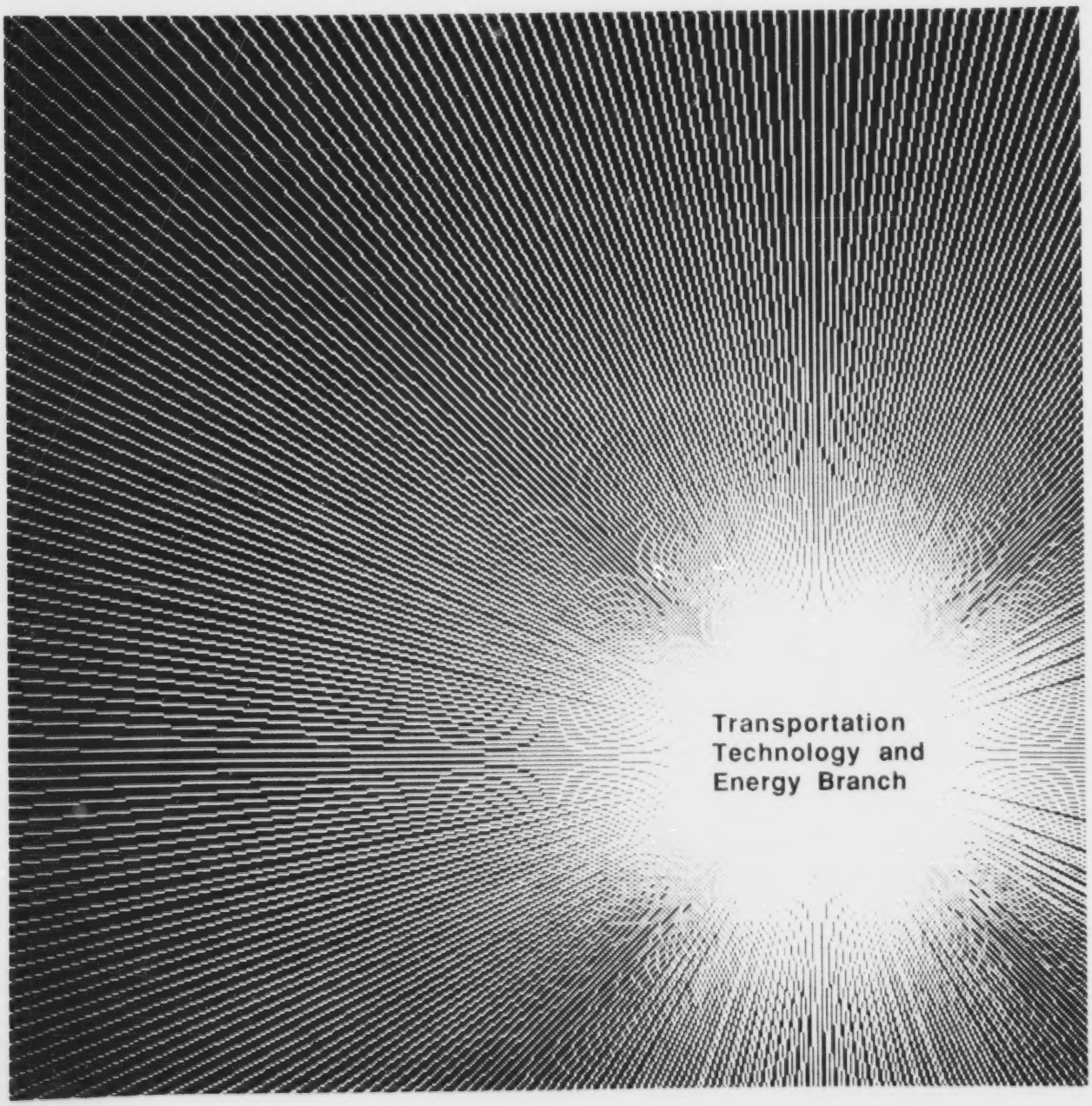
Ontario

Ministry
of
Transportation

Transportation
Technology and
Energy Branch

Transportation Technology Perspectives: The 1990s and Beyond

Conference Proceedings



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Conference Proceedings

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*Transcribed from conference recording

OVERVIEW

The Transportation Technology and Energy Branch of the Ministry of Transportation, with its mandate to be the provincial government's focus for research, development, and demonstrations in areas of transportation technology and energy, organized the symposium, "Transportation Technology Perspectives: The 1990s and Beyond." The goal of the conference was to review and renew our research strategies, to advance our knowledge of the rapidly changing transportation technologies and their impacts on our environment, and to share this knowledge with our partners in transportation.

To achieve these objectives, transportation experts from various levels of government, industry, academia, and research organizations were invited to participate in the symposium, presenting papers and partaking in discussions on emerging technologies, and their role in addressing the transportation challenges of the 1990s.

The papers and discussions of the symposium are presented in these proceedings. They show that technology is a major tool to be used in addressing the current issues in transportation, such as congestion and its eroding effects on our standard of living, safety, efficiency, and impacts on the environment. The papers and discussions also show that in addressing these issues, a wide range of advanced and emerging technologies are employed:

- intelligent vehicle/highway systems
- automation and control
- advanced rail technologies
- automotive efficiency
- alternative fuel technologies

In the presentations and discussions, it was consistently stressed that not single technologies, but integrated systems, will provide the appropriate approaches to our transportation challenges. Transportation technology itself, in a broader sense, was described by many participants as an enabling technology that contributes to the attainment of our overall societal goals by increasing mobility, providing access to our social functions and services, and contributing to the vitality and competitiveness of our industrial sector by providing products and services.

Throughout the symposium it was also pointed out that not only is the technological content important in providing a strong transportation system and industry, but also the processes employed in developing and implementing the technologies are vital to the eventual success of these technologies.

Particularly, the importance of a team approach in technology development and implementation was stressed, as was the process of harnessing of inventions into innovations in the delivery of actual end products and services. In order to maintain a competitive position for Canada's transportation related industry, it was seen to be necessary to establish a leadership position in well defined, focused areas, and not be satisfied with mediocrity, nor to be spread too thinly over too many areas.

It was also pointed out that environmental concerns are becoming driving forces in the development of new technologies.

The symposium provided observations on the status of transportation R&D in Canada, its strengths and its weaknesses. It was noted that although the team approach is gaining acceptance, it is still weak in many areas.

There seems to be insufficient integration of the resources and talents of government, industry, academia, and research organizations. Also, the process of implementation of inventions and new technologies is insufficiently developed.

Nevertheless, some sectors of Canada's industry have demonstrated the ability to achieve leadership positions, as illustrated by the development of the Canadian space arm. There appears also to be potential for leadership in the transportation sector, especially in the areas of transit and alternative fuels technologies.

The papers and discussions presented in the following proceedings examine and analyze these topics in greater detail, and give perspectives from the viewpoints of industry, government, academia, and research organizations. They provide information as well as direction, and can be a useful guide in the development of future directions for transportation technology research, development, and demonstrations within the ministry, and in the formulation of strategies for the Canadian transportation industry.

KEYNOTE ADDRESS

Kimon Valaskakis

Dr. Valaskakis is Professor of Economics at the University of Montreal, President of the Gamma Institute, and author of several books, the most recent being Canada in the Nineties: Meltdown or Renaissance?

Ladies and gentlemen, it is indeed a pleasure to be with you. I have had the pleasure of working with Ontario Transportation before. About ten years ago, Mike Ernesaks invited me to work with his group on technology, Technology Outlooks Office and it was an extremely pleasant experience and a learning experience, I think, for both of us. I must say I enjoyed it very much. My only gripe is, why did they wait ten years to invite me again? So, I guess it is a-once-a-decade thing.

What I would like to do with you in these few moments we have together is, since this is 1990, the first year of the last decade of the 20th century, to begin by picking up a few of the lessons of the 80s. As I said, ten years ago I had the pleasure of working with the transportation ministry in Ontario. I'd like to look back as a first step and see what happened in the 80s. Not what happened from every point of view because that would be too large, but what happened from a focus point of view and then move on to look at what I think the prospects of the 90s are in the fields that are relevant to the theme of this conference, which is technology and transportation. And finally, come up with some comments on how I think Canada fits into the whole thing, how Ontario and Canada fit into the whole thing and give you some of the ideas that I am expressing in that book that has recently been published.

Let us begin then by looking at what happened in the 80s. As I said, I think it would be a mistake to try and be too encyclopaedic. I don't think we should look at everything that happened and try and make sense out of that because that would be too large. I would like just to focus on two or three things.

One of the things we were mentioning in the early 80s, in 1980, when we did this study, was that the global situation, the world economic situation, was changing and was changing rapidly. New players were coming on the scene and new conditions were prevailing. What were these new players and these new conditions? Well, much of what we were saying in 1980, I think, did come about. Some of it came about much faster than we thought, some of it came about slower than we thought. But basically, what we were saying then is that technology was becoming a key factor of growth. That was the first thing we were saying. The second thing we were saying was that price competition was an important feature in the new world situation that was prevailing in the 80s and that would attract a number of new players.

The third thing we didn't say, but in retrospect it did come about, was that a success factor in the 80s was not only price competition, but quality competition. If you look at what the Japanese have done in the 80s you find that a lot of their penetration in the world global market has been as a result of quality control. Total quality control. Bringing the best quality to the customer, making quality into a fine art, making it into something that can be perfected.

These three factors, technology competition, and in particular one field of technology and competition, information technology, because I think the 80s was to some extent the decade of information technology, together with price competition and quality competition, brought about a new pattern in the world situation which could be I think described in terms of number of players, a number of emerging actors in the scene.

One prominent actor that came about was the newly industrializing countries, the so-called NICs. The NIC of South-East Asia, not just Japan, but more importantly perhaps South Korea, Hong Kong, Taiwan and Singapore which came on the scene using price competition, presenting goods which were cheaper than other goods and also presenting a high-quality product,

a good product. They came in on the scene and basically they engendered a certain movement of industrialization in these areas which was matched by a counter-movement of the industrialization in other areas.

So on the one hand, we have the NICs in the 80s, the newly industrializing countries, and we also had, if you permit the acronym, the DICs or the de-industrializing countries, basically, to some extent, the European countries and North American countries, losing industries to these newly industrializing areas.

The third group of players in the 80s were the what I called the RICs or the re-industrializing countries, countries that had been industrialized and went through a second industrialization by adapting to the new scheme of things by adopting the new technologies, but by harnessing these new technologies for competitive advantage and I think one example of the re-industrializing country has been Japan. Because Japan industrialized way back, it industrialized in the thirties, in fact its take-off can be dated all the way back to the Meiji Revolution in the 1860s.

But what is very fascinating about Japan is that they keep taking off. They take off, they take off again, they take off again, and they can adapt to the new revolutions. And I think the re-industrializing character, the re-industrializing feature of the Japanese economy is to be distinguished from the newly industrializing countries of South-East Asia, mainly the other ones, Hong Kong, Singapore, Taiwan and some newly industrializing countries of Latin America like Brazil, too.

Now, we had the newly industrializing countries and we had the re-industrializing countries and we had the de-industrializing countries, we had the rentiers, the rentiers were countries who could live on their natural resources. Canada was one of these countries to a large extent because, in 1980, we were also still thinking in terms of energy crisis. We were thinking in terms of resources and if you had resources, if you had energy, then you would be in good shape. So some countries were becoming rentiers and were living from their resources.

And then, the fifth category was the Third World with no industry, no old industry, no new industry, no resources and therefore completely poor.

And I think this topology of countries, the NICs, the RICs the de-industrializing countries, the rentiers and the Third World could be said to be an accurate description of what has happened in the 80s with industrialization as the key theme and de-industrialization as the key theme.

And as an example of de-industrialization, I think we can take an example in your area, transportation, and if we look at what has happened to automobile production and automobile industries, we find exactly that pattern. In the late 70s we still had in Britain a car industry, an automobile industry. We had British cars that were still on the scene, they were being sold and had some reputation for quality. Today, we have very few British cars; the British automobile industry has more or less disappeared. Even the quintessential British sports car has been usurped by the Japanese clone the Miata, produced by Mazda, which is supposed to be the exact emulation of the British sports car.

So, we find that the automobile industry has migrated, has gone to the south east, to South East Asia, and we find to a large extent that the North American automobile industry has also been extremely attacked, and – to some extent – defeated in the 1980s by both South East Asian competition and European competition.

In the early 80s, the Japanese manufacturers became more productive than the American manufacturers. They surpassed the volume of production and slowly what we saw was not only a price competition but a quality competition with Japanese luxury cars appearing on the market in the middle 80s and becoming dominant.

One of the things that struck me the other day, I was reading *Car and Driver* magazine and they had a so-called shoot-out between the luxury cars of the world. They had Cadillac, BMW, Jaguar, Mercedes, Audi, and Infiniti by Toyota, I believe, and the other one, Lexus. Now two Japanese cars, four European and one North American. Which was at the bottom of the heap? The North American car, judged by both objective indicators

and judged by subjective indicators. Then came Jaguar, then came Mercedes, then came BMW, then came Audi, and number one and number two of the luxury car market was judged to be the Japanese cars. So, again, this would have been unthinkable in the early 80s but I think it shows the degree of change and how rapidly things can change in a decade.

So, this was the message of the 80s. Now we are in the dawn of the 90s and what is the message ahead of us?

I would like to suggest to you that in the 90s, we have a number of success factors that are coming on the scene. Some of these success factors in international competition are a confirmation of what happened in the 80s and some of the success factors are going to be absolutely new.

I would like to focus on two success factors with you today. One of them is the new and enhanced role of technology in ways that we didn't even imagine in the 1980s. Now I would like to say something about that. It's extremely important to distinguish between generic, or strategic, technologies on the one hand and sectoral technologies on the other. And what I think we must realize is that the generic, or strategic, technologies are much more important in terms of their impact, in terms of their linkages, than the sectoral technologies.

The Japanese have a very good model to understand this in what they call the bonsai technology model. I'm sure many of you are familiar with it. But basically they see technology as a bonsai tree. And in that tree there are roots, there is a trunk, and there are branches, and there are leaves. The roots of the tree are the generic technologies, this is new material technologies, these are bio-technologies, these are information technologies, these are telecommunication technologies, something which is really fundamental.

The roots of the tree would then combine. These generic technologies combine to make a trunk. The trunk is a group of technologies that have some cohesion. It could be informatics, it could be aerospace, it could be transportation.

From the trunk of the tree, then you have branches. And these branches are wide and varied. One of the branches might be applications in the field itself, transportation applications in transportation, information technology applications in information technology. But what is important to realize is that there are branches that have nothing to do with the field itself. Hence, the status of a generic technology.

Information technology, for instance, affects all the other fields that you can think of, not just the field of information technology. There are other branches. And these other branches in turn have smaller branches and then you get to the leaves. And the leaves are the products. The leaves are the services, the leaves are what we consume every day.

But the interesting thing about the Japanese approach is that they say you Westerners, you start with the leaves. You start with the leaves and you compete on the level of the leaves. We start with the roots. We have strong roots. The strong roots will give us a trunk, the trunk will give us the branches and then the leaves, well, that's child's play. We can compete on the level of the leaves because we have that strength at the bottom.

Now another important thing in the bonsai model is it doesn't really matter who invented the wheel. It doesn't really matter who invented the micro-processor, or new materials. At the root level it could be world technology. But they take this world technology, they make it into that trunk, they transform it and then it goes into the branches and they have a common trunk for all these branches and then the leaves are again the final effect of this sort of approach.

I would like to suggest to you that the bonsai model, the linkage model, the idea of having strategic linkages of technology forward and backward, but especially forward, this is becoming a key success factor of the 90s. And I would like to give an illustration of that key success factor of the 90s by telling you a little bit about the project we did for the Information Technology Association of Canada where we tried to establish how information technology is a key success factor in areas that have nothing to do with information technology.

This is where we alighted upon a concept which I think has a lot of communication potential in it. This concept is the concept of the enabling effect. The verb to enable has a number of synonyms, you can think of enabling as empowering, as making able, as allowing to. We were commissioned to try to show how information technology enables other fields to do things that they otherwise would not be able to do.

We were commissioned to try to develop indicators of this so-called enabling effect. Especially given the fact that when you look at something like information technology, information technology and the information revolution is present everywhere, except, unfortunately, in the national accounts. In the national accounts, if you look at the contribution of the information technology sector, you find that it's only 2 or 3% of the gross national product and its employment figures are very, very small. So, looking at it from the outside, people might conclude erroneously that information technology is not as important as textiles, is not as important as pulp and paper, is not as important as any of these things. And yet, information technology has this enabling characteristic which allows the other sectors to do much more than previously.

Another thing which motivated the study was the fact that small and medium-size enterprises tend not to invest in information technology because they cannot see the immediate payoff. It's a question of immediate payoff and they say well, what does it do? What does it do that we can't do with less sophisticated means? Once again, if you look at the enabling effects, we come to very different conclusions than if we don't look at the enabling effects.

So what are the enabling effects of information technology and to what extent can this model be generalized?

Well, what we tried to do in the context of this study is to develop a model with 20 indicators falling into five groups. We said the enabling effect of information technology is first perceived at level one. Level one, basically, is cost reduction. Cost reduction is quantifiable, cost reduction is measurable and it's even found in the national statistics. It shouldn't be too difficult to identify. What kind of indicator would be present there? Well, cost reduction, in the form of low dollar input, of low time input, of low labour input, of low material input. Here we have level one and the enabling effect at level one should pose no problem.

But, as you go up in the scale of enabling, as you go up into the intensity of the enabling effect, a strange thing happens. The more the enabling effect is intense, the less it's measurable. And the less it is intense, the more it's measurable.

Consider level two: Level two of our enabling model says that the impact of information technology is no longer on cost reduction, but on quality enhancement. So how do you measure quality enhancement? Well, the Japanese propose the five zeros, the five zero measurement: zero defects, zero delays in production, zero maintenance, and all these things. And these could be a starting point.

But unfortunately, what happens, is that if an entire industry goes through qualitative change, if for instance our cars do not have to be serviced as often as they used to, then, it's somewhat lost in the wash. If one competitor improves his quality and then seizes a larger market share from the others, then this is measurable. But if all the competitors do that because an entire industry is upgraded, the quality is somewhat difficult to measure. And yet it *is* present.

So, the attempts to measure quality by starting with the five zeros approach has been the approach that we have suggested in order to get to level two, in order to try to understand how information technology enables firms, enables sectors, enables regions to produce goods and services and better quality.

Then we come to level three of enablement. And in level three of enablement we come up with a number of fundamentally new products and services that did not exist before and could not exist without I.T., without information technology, because it is completely I.T. dependant.

Let me give you an example: electronic agendas. Although they are agendas, they are basically a

different product from the paper agendas, because they can only exist because I.T. is there. The *Globe and Mail* is published as a national newspaper. It's a satellite newspaper. Now it's a newspaper and yet it's a new product which is totally I.T. dependent because of the way it's being produced.

Financial debit cards, not credit cards but debit cards, which automatically allow your bank account to be debited whenever you make an expense because it has an intelligent chip in it.

Airline reservations. A number of products that we take for granted today, are in fact I.T. dependant and have been enabled by the presence of I.T. Had we not had I.T., we just could not have these products. And therefore, the very existence of these products becomes the indicator of enablement and it would be confusing to consider the *Globe and Mail* or the *New York Herald Tribune* as being exactly the same product as a newspaper that is produced by a more traditional means.

But what is level four? Level four of enablement gets into strategic management. Strategic management is probably one of the most important sub-elements in success factors in international competition. It could involve strategic planning, it could involve just-in-time management, it could involve flexible manufacturing systems, it could involve internal communications systems, external communications systems, image building. All these areas are enabled with the use of I.T. When you talk about communications systems, you think of desktop publishing, internal memos, external memos. When you think of a lot of the other things, you think of control systems, you think of some of the things that are being exhibited right at this conference. And here you get to level four, which is the level of strategic management. New ways of managing our enterprise and new ways of becoming competitive. This is less measurable in a direct sense, but more important in an indirect sense, because all these things, all this strategic management could in the final analysis make the difference between a successful niche in the competitive world market and an unsuccessful one.

Finally, the fifth level of I.T and I.T. enablement is what we call new concepts and paradigms. New ways of looking at things, new ways of understanding the world, and in fact, the impact on our brain of artificial intelligence. Not the impact of our brain *on* artificial intelligence, but the reverse process. If you look at some of the software items that exist today on the mass market, you find that a number of them are fundamentally altering the way we think.

Think of the software item in the Macintosh group called Hypercard. Hypermedia, hyperbooks. This is a new way of organizing knowledge, of organizing information, which has a fundamental impact on the way we think.

Computer assisted thinking. The thinking process that we are involved with. That which is at the heart of what makes a human being a human being is now assisted, is now enabled by information technology. And as artificial intelligence becomes more commonplace as it will be in the 90s, then this computer assisted thinking will become more and more important.

And again, if you take the five levels of enablement from cost reduction all the way to computer assisted thinking, the implications for competitiveness are immense, because one of the things that the enabling effect has done is to flatten out organization charts, to reduce the middle management bulge to make the corporate structures much more flexible. It has also made time to market, or time to competition, a much more crucial variable success than previously.

Things are moving so fast and the possibilities of leap frog are so great that unless you have a new product and you come to market quickly enough, someone else is going to leap frog you. I was looking at some of the state-of-the-art devices that have been exhibited at today's conference and I say let's get them to market, let's get them to the export scene before we get leap frogged because the Japanese are waiting and they are going to leap frog us if we are not careful. And in fact, one of the competitive maxims that comes out of the enabling effect is an inversion of the famous adage "better late than never." Now the answer is "better never than late." If you are going to be late, better never. You

missed the boat, you better not enter the scene in the first place because you won't be able to compete.

So, what can we conclude from the enabling effect? We can conclude that in a generic technology like information technology, the linkages are so great, the upstream effects are so great, the downstream effects are so great, that basically we have a strategic technology, a key technology. This key technology is now to international competition, I would claim, something like anabolic steroids to Olympic competition, with the difference that it's not illegal and it's so far not bad for the health.

So, everybody uses them, and if you don't use them then you put yourself at a competitive disadvantage. And to a large extent, that is the name of the game. I haven't looked at it carefully enough, but I believe that the same kind of enabling model or a similar adjusted enabling model could be developed with transportation as a key technology. If you put transportation in the trunk of the bonsai and look at the roots and at the branches, the case, the compelling case, for the importance of transportation would be much stronger than if you look at the direct effects of transportation, which, as in the case of information technology, will greatly understate the reality.

So, I believe that the enabling model -- either that particular model or other similar models -- is something that has to be generalized and should become the basis of a national technology policy for Canada or for Ontario or for industry groups where linkages are looked at rather than looking at the leaves and at the sectors one by one.

I said I was going to focus on two success factors. Technology is one of them. I am going to focus on the other one because I think it is equally important. I believe that on the institutional front, the world economy has shifted from one type of model to another. And we have to understand the kind of model that we have shifted towards if we are going to be successful in international competition.

I was in Milan, Italy, in December. I was one of the speakers in a think-tank session for Italian businessmen. There was Alvin Toffler from the U.S. and some people from Europe and some people from Japan. We looked at the 90s and we were trying to get some meaning about the 90s. Everybody had his own ideas and his own vision. But one thing we all agreed was that one of the things we have to do is to re-write the history, the political and economic history, of the 20th century and especially the evaluation of what happened in the Second World War.

At the end of the Second World War, we said that there were three winners and three losers. The three winners were the United States, Great Britain, and the USSR. If we look at the international situation now, the USSR is in very bad shape. Britain has de-industrialized in spite of what Mrs. Thatcher has done; it is now in a position much weaker than it was in 1945. And the United States, although Russia has lost, I would argue the United States has not won. The United States has also de-industrialized, has also suffered economically and is also in bad shape.

We also said that in the Second World War there were three losers: Germany, Japan, Italy. Japan is doing extremely well; it is number one. Germany is on the point of becoming number two. With a United Germany, it is extremely strong; a United Germany has a GNP bigger than France's and Britain's combined. It's so dynamic that it scares all the other Europeans. And Italy has a dynamism, has an innovation, has an economic momentum that is very, very striking.

So, the winners were not winners and the losers were not losers. What does this all mean? I think what that means is that Communism has shown itself to be a loser, but I think that the winner has not been U.S.-style Capitalism. I think the winner is likely to be a new form of Capitalism which I would tentatively call "team capitalism." And the characteristics of team capitalism is that you no longer go one on one against competitors. You go many on many. It is the Japanese model. It is the Western European model. And I think what we are looking at in the world today is the emergence to some extent of the Japanese superstate which is already there, but we are also looking at the emergence of the European superstate. Because what is happening in Europe is a form of team capitalism.

I came to Toronto from Montreal today not with a Boeing, not with a McDonnell Douglas, I came with an Airbus by Air Canada. Air Canada has been buying Airbuses. U.S. companies are buying Airbuses. The Airbus is the same sort of present threat to the aerospace industry, another industry that we have had the opportunity to look into, that the automobiles were in the 80s. And what I think may happen in aerospace in the 90s is exactly what happened to automobiles in the 80s. The present threat is a European threat of Airbus and the longer term threat is the Japanese threat of better planes. A Japanese leap frog, so that a decade from now when the Ministry of Transportation will invite me again in the year 2000, we would probably be coming in with a Mitsubishi plane rather than an Airbus or McDonnell Douglas or Boeing if we are not careful.

Now what do the Europeans have and what do the Japanese have that we don't seem to have? I would suggest to you that they have teamwork. The way MITI organizes itself, the way the public sector and the private sector work together is a marvel of co-ordination. And the Europeans are working together, too. There is a government/private sector co-operation and Airbus has the support, not of one government, but of four governments and is a conglomerate.

So the team capitalism that I am talking about is the concerted approach. It's the public sector and the private sector working together, and I would claim that this is a key success factor in most industries, if you want to compete on the international scene. It is also the teamwork between labour and management. It's the teamwork between companies that network and create strategic alliances with each other. And it is an approach that substitutes group competition for individual competition. In a nutshell, I would like to argue that the international economic game has shifted from a game which used to resemble singles tennis, one on one, to a game that resembles American football, Canadian hockey or European soccer, where teamwork is the key thing. It would be unthinkable in American football for everybody to go his own way. It is very, very close teamwork, everything is pre-planned. Same thing with hockey. Over the years the Soviets and the Europeans have taught us that a group of medium hockey players could defeat a collection of superstars if these superstars do not work together.

So, team capitalism, matched with technological enablement, are the success factors of the 80s. And now I come to the last part of my communication, which is: Where do we all fit here in Canada?

I would like to say in a nutshell, as I was introduced and the book title was introduced, the name of my book is *Canada in the Nineties* but the sub-title is the thesis, the sub-title is *Meltdown or Renaissance?* I sincerely believe that the Achilles' heel of Canada today is precisely the lack of teamwork; that we have now entered into a team capitalist phase of the world economy, that it is teams against teams. And what we have in Canada is, on the contrary, multiple adversary systems.

The most visible of the adversary systems is the one that opposes the federal and provincial levels of governments. We have eleven governments: we have the federal government and ten provincial governments. Soon with the territorial governments, we will have thirteen. Each of these governments will be quasi-sovereign in their areas. The result is that we have 25 million people and we have all these levels of government that do not work together. In a nutshell, I don't think we can compete under these conditions. In industry after industry, I think, it can be shown that we cannot compete under the conditions of strife within the public sector.

The second adversary system is the public sector versus the private sector. MITI and the Japanese work hand in hand, the West Germans and the German industry, the French and the French industry work very close in hand. Even Mrs. Thatcher and her completely free-market ideology works very closely with British aerospace and with the British industry. Whereas all these things are happening, the public sector and private sector does not have, in my view, the cohesion that is needed in Canada. Probably neither in the U.S. But Canada for sure does not have the cohesion that is necessary to meet international competition.

Third adversary system: labour versus management. Labour versus management was the big adversary system of the 1970s. In the 80s that adversary system was put on the back burner, mainly because labour has become much weaker as a driving force in the economy. But with the kind of things that are likely to happen in the 90s, unless labour and management work very closely together, we are going to have an adversary system worse than the 80s with the result that innovation will be blocked and that we won't be able to do what we want to do in order to be competitive.

And the last adversary system is the small firm versus small firm syndrome. I think Canada, in some sense, is too big and too small. It's too big size-wise and yet our firms are too small to compete. Our fiscal policies, our monetary polices, our government policies, unfortunately with excellent intentions, tend to encourage smallness. The networks, the strategic alliances, and the group effort is what is really making the difference.

What is happening throughout the world is mergers and acquisitions. And Canada, this is been the complaint of the aerospace industry, is very often not invited to these mergers and acquisitions parties. It's been left out. And therefore we will be condemning ourselves to send dwarfs against giants, and we cannot compete under these conditions.

Now, is it inevitable meltdown? No. This is why I think we have a tremendous opportunity for renaissance because both on the subjective level and on the objective level, the strengths are there. On the objective level we have a number of state-of-the-art niches. Some of them are exhibited in this very hotel. Others are in industries like telecommunications where in some areas we can, I think, accurately say we are number one. In aerospace, in control systems, in simulation systems, we are also state-of-the-art. In robot arms we are very good. And so on. There are a lot of objective strengths.

There are also a lot of subjective strengths: One of the things that is quite fascinating is to discover that Canada's image abroad is much better than its self-image. Everybody admires Canada, much more than Canada admires itself. In fact, there was a recent survey before one of the western summits and the people in the countries of Europe were asked "which country do you admire most after your own, which country would you rather live in after your own?" And overwhelmingly, people chose Canada, because it has such a good image.

Another indicator of the good image, an exaggerated indicator: the British periodical, *The Economist,* had an article in November about Meech Lake. And they said Canada is such a happy country, such a wealthy country, such a carefree country, that it was forced to invent something to keep itself from being bored. And it invented Meech Lake. There is nothing behind it, everything is fine, but rather than be bored silly with maple leaves, maple syrup and wheat and all these things, the Canadians invented Meech Lake.

A final image, subjective-wise, and a more substantial one is the one that was recently given by a Swiss think-tank which polled a number of businessmen in terms of competitiveness. Canada, to my surprise, came out forth in the world, after Japan, after West Germany, Switzerland, Canada was perceived as number four. I think what the businessmen meant was *potentially* number four, from that point of view, not actually number four.

And this is where I think we have a tremendous opportunity to turn the whole thing around. If we recognize the challenges that exist abroad, the challenges of the world economy, the new success factors like the enabling effect of technology, like the institutional changes that go with it and realize that we cannot win hockey games or economic games by solo approaches.

The sooner we realize that, the more we will be able to fulfil as a country, as a region, as a sector, the sooner we will be able to realize our potential. The more we postpone or the more we ignore these facts and we try to muddle through, the more we are likely to come up with the inevitable penalty of muddling through which is, at the worst case, meltdown and the disappearance of the country, because I think this is a very real threat today. And at the other extreme, even if it's not the disappearance of the country, mediocrity. Mediocrity in

performance, middling performance. One of the things that concerns me is that perhaps we have too much of a cult of middleness. We are middle power, we do everything in a middle way and therefore we don't go for the gold, we go for the bronze, even when the gold is available. I think the gold *is* available, the gold is possible. We have to work for it. We have to work for it in each sector and in each key technology by looking at the linkages with everything else and developing a unifying and completely comprehensive approach, a national plan, a Team Canada approach.

OPENING REMARKS

Pat Jacobsen

Pat Jacobsen is the Deputy Minister of the Ministry of Transportation of Ontario. A political science graduate from the University of Manitoba, Ms Jacobsen is also a member of the Executive of the Institute for Public Administration of Canada and the Board of Directors for the Roads and Transportation Association of Canada.

I think it's quite fitting, the last time I was in this room, it was my second day on the job. It also was a future technology and issues meeting. I feel a lot more comfortable today than I felt six months ago, addressing -- how many hundreds of people where there? -- 300, I guess it was.

I think that those of you who, over the last six months, have been working with me certainly know my interest in the issues that are related to technology. I think, in fact, sometimes, with the discussions we get into, some of the staff are concerned that they can't brief me fast enough on what we have been doing, before I leap to discussions about what we *should* be doing and then find out we have been doing it before it was even popular.

So, I welcome all those of you who've come from outside the province, from other countries, and from other jurisdictions in Canada. I think that the only way that we can all collectively work on issues like this is if we *do* share information. I don't think any of us have enough money, and certainly Milt often reminds me of that, in any of our jurisdictions to go it alone. I don't think any of us have private sector companies that have sufficient money in R&D to go it alone. And so, therefore, collectively we've got to find a better ways to share that information in a non-competitive way.

One thing that I'm particularly interested in, in terms of the technology, is any opportunities that we can use in Ontario, where we can use our technology and our companies' technology to market abroad. I think that's something that in terms of our ministry we would be very, very interested in. And those of you who are from the private sector, or those of you who are involved in private sector relationships, if there are any ways that we can further the development of those technologies and the marketing of them abroad, then as a ministry and also in connection with that, Industry and Trade and their support, we're very interested in issues such as that.

The second issue that I'd like to raise is manpower, or human resource power, I guess I should say. We are very interested in anything that furthers people being involved in those issues. I don't know whether any of you followed an announcement by the minister for education earlier this week, who announced that the public school system was going to put a fairly healthy influx of money into certain areas of development, of curriculum development. There were three areas; and two of those areas I think directly apply to us. One was specifically transportation and the other was micro-electronics. And there is the first, I'd say, massive influx of money into the school system to develop materials, to purchase equipment, to do counselling, and to aggressively go after getting young people interested in careers in those areas. That's something that certainly concerns all of us in this room and concerns us as a country, when you start to look at the numbers that are actually dropping in terms of people going into those kind of fields.

And I guess the third and last personal issue that I would raise is that at a time when many of us were into technology and energy-saving issues before in some respects they were as popular as they are now, and I think that we kind of got into things in an energy way, then when the energy crisis was gone I think everyone felt, well, there is no reason to be looking into these kinds of issues. I think that government and private companies stopped funding certain types of things, we all cut back, we plowed our resources into other areas. And those lonely souls who trudged on in the years when it was not popular I give a strong tribute to,

because with the emerging concern over the environment, I think it's only the work of the people in my ministry and the rest of you, who because of your work will position us in such a way that we can take advantage of some of the things that we're going to have to do as a result of congestion, as a result of the growing concerns in terms of the environment. I would say that for those of you who were there before it was popular, I certainly give you a lot of credit and I certainly say that as governments, we've got to find ways to make sure that we can build on that.

I wish you all a good meeting. I am going back to an equally enjoyable period: I'm going to the public accounts committee to explain why something happened before I was there, three years ago.

I look forward to hearing the outputs of all of this and I give you my ministry's commitment that we're very interested in the issues of technology. And I think that it's the kind of issues that as a ministry we want to be in the forefront. Have a good day.

PLENARY ADDRESS

Dr. Richard R. John

Richard R. John is Acting Director and Chief Scientist of the Transportation Systems Center, a component of Research and Special Programs Administration of the U.S. Department of Transportation. Dr. John received his undergraduate and graduate training in engineering physics and aeronautical engineering at Princeton University. He has published extensively in the fields of combustion, high temperature gas flows, advanced space propulsion, and most recently, on industrial competiveness.

I/ Background

The purpose of this conference is to review and renew the research strategies of the Ministry's Transportation Technology and Energy Branch. I have been asked to take a broad and multimodal approach to transportation technology, to assess the opportunities and impediments to harnessing technology, paying particular concern to such things as public acceptability, affordability, energy, and the environment – and, all within one hour – at least, I have a challenge.

During this week, in which you are having your conference, by sheer coincidence our Secretary of Transportation Samuel Skinner is releasing the long-heralded National Transportation Policy. I have been fortunate in serving as a support member to the National Transportation Policy team and have been able to observe, at first hand, its development.

Since I have been involved with the National Transportation Policy, I thought it might be useful for this group if I reviewed the development process and culled out a few observations and results that might be useful for your current deliberations.

Secretary Skinner introduced the need for a National Transportation Policy and made it his first priority, after transportation safety, at his confirmation hearings in January, 1989.

Slide #1

"The goal of transportation planning and policy is to ensure the nation's economic, military and political competitive position in the world and to ensure quality transportation for the nation. There is a need for planning because the system can only be as good as the plans and policies developed for it."

Samuel K. Skinner
Secretary of Transportation
January, 1989

A major driving force for the development of a National Transportation Policy at this time is the pending reauthorization of the federal aviation, highway, mass transit, and highway safety programs.

Slide #2

Upcoming Reauthorizations
- Aviation Programs
- Highway Programs
- Mass Transit Programs
- Highway Safety Programs

The strategic planning process being used to build the National Transportation Policy began in February 1989 and will reach a milestone this week with the distribution of the National Transportation Policy.

Slide #3

Blueprint for Building the National Transportation Policy
- Framing the Policy Debate
  January – July 1989
- Eliciting the Views of Transportation Users and Providers
  July – September 1989
- National Transportation Policy Statement
  March, 1990

2/ Factors Influencing Transportation

Before presenting the framework for the policy debate and the views of transportation users and providers, it is useful to describe a few of the driving forces currently impacting transportation.

Slide #4
Factors Influencing Transportation – 1990-2000

- Continuing Concern About Safety and Security
  - Drug and Alcohol Abuse
  - International Terrorism
- Demographics
  - Middle Aging of the Nation
  - Feminization of Work
  - Changing Nature of New Workers
- Enhanced Environmental Awareness
  - GlobalWarming
  - Urban Smog
  - Catastrophic Oil Spills
  - Land Use/Wetlands
- Economics
  - Globalization of the Economy
  - A 'Lighter Economy'
- Politics
  - Trend to Local Decision Making at All Levels
  - Multi-Polar World
- Time
  - Time is becoming the Scarcest Commodity

There is increasing recognition that human failings are, in one way or another, the cause of more than 70% of transportation-related accidents. In a recent press conference the Secretary indicated that one of the biggest, if not his biggest challenge since coming into the Department has been in establishing an appropriate response to international terrorism and its threat to transportation security.

From a demographic viewpoint the nation's population is getting older. There are more years for retirement, more time for travel and increasing demands on transportation system. Feminization of the workforce means two- and even three car families. In some parts of the country its not out of the question for three and four members of a family to each have a car and go off to work in different places each morning, sometimes as far as a hundred miles apart. The rate of car ownership is in some cases even growing faster than the rate of population growth.

The nature of the workforce is changing. By the year 2000 only 15% of entrants to the workforce will be the traditional white male. Are we getting ready for the future transportation trainees? Will we have trained enough engineers and planners? Who will be thinking about future transportation systems?

The environment is reaching centre-stage on national and international agendas. Global warming, urban smog, catastrophic oil spills are front page news. In the early 1950s the New Jersey Turnpike was built through one of the most heavily industrialized areas in the United States in less then two years. Just imagine trying to do that today.

We are dealing with a globalized economy. The fraction of our gross national product which is exported or imported is currently at 20% and growing. There is increasing concern with getting cargo from the dock to the rail head in the face of growing urban congestion.

We have a 'lighter' economy. The value of a pound of gross national product is increasing. A pound of consumer electronics, such as video cassette recorders, costs much more than a pound of steel. What does this mean for transportation? The transportation officer has become the logistics officer who will trade off high cost, rapid transportation and resulting low inventories for low cost, slow transportation and resulting large inventories.

Politically, there is a national and international trend to local as opposed to central decision making. The bipolar world of the last fifty years has become

multipolar. Regional economic competitiveness is replacing national military competitiveness.

Reflecting these trends, transportation decision making is moving to the local and regional level and away from the central government.

As we enter the 1990s and move into the 21st century, time is becoming our most precious commodity. Think of two, three and four member households, each having separate jobs and trying to take vacations together. With the growing concern about the scarcity of time, quality and on-time transportation will take on an increasing significance.

3/ Framing the Policy Debate

The policy debate has been framed around the premise that transportation is an enabling industry. Transportation is a means to an end. The purpose of transportation is to move people and goods in an effective, efficient, and safe manner.

Slide #5

National Transportation Goals

- Transportation system must ensure:
  - Global Competitiveness
  - National Mobility
  - National Security

- And, be compatible with:
  - Citizens Safety (Public Health)
  - Environmental Preservation
  - Energy Security

The effective and efficient movement of people and goods is an essential element in the ability of a locality, region, or nation to compete in a global economy. National mobility or the ability of all members of society to move freely from one place to another is one essential measure of quality of life.

Finally, a nation's security is critically dependent on the viability of its transportation system.

Slide #6

Transportation Markets

MULTIMODAL MARKETS	MODAL PERSPECTIVE					
	AIR	MARINE	HIGHWAY	RAIL	HIGHWAY	TRANSIT
INTERCITY PASSENGER						→
INTERCITY FREIGHT	→					→
URBAN SUBURBAN	→					→
RURAL		→				→

4/ Transportation Markets

Traditionally governments view transportation as divided into modes, e.g., highways, rail, air, water, and transit. Studies are usually confined to a single mode of transportation; decisions are made along modal lines and international and multimodal solutions. The outreach activities used to elicit the views of the transportation community were based on assessments of transportation markets, for example, intercity passenger, intercity freight, urban/suburban and rural, rather than by mode.

The constituencies for the transportation system are you and I, the traveller, the shipper, and the regions served by the system. These are the people who pay the bills and vote or don't vote for gasoline taxes.

One of the major purposes of the statement of National Transportation Policy is to create awareness of the importance of transportation and to enhance the role and priority of transportation on the national agenda.

5/ Intercity Passenger and Freight Transportation

As part of the outreach activities, seminars and workshops were held at different locations around the country on the different multimodal markets. To illustrate, I will summarize a few of our findings on intercity passenger and intercity freight transportation.

Slide #7

Intercity Passenger Transportation Findings

- Continuing growth of intercity and intermodal passenger transportation
- Shift of travel dominance: business to personal
- Growth in international and domestic tourism
- Hypersonic transport economics are uncertain
- No travel - reduction impacts of communications are evident

Two-thirds of air travellers are now people travelling on personal business; only one-third are business travellers. There is astounding growth in tourism; it has become an international two-trillion dollar a year business. Our biggest export in the United States is tourist services to overseas visitors. As a nation we get more import dollars from tourism than Boeing makes selling planes to overseas customers. Thus far there is no clear evidence that enhanced communication capabilities is cutting down the need for travel. In fact the more people electronically communicate with each other, the more they want to "touch the flesh."

Slide #8

Intercity Freight Transportation Findings

- Global sourcing and distribution
- Future drivers: just-in-time/competitiveness
- Future needs: seamless logistics services
- Cargo is becoming lighter more valuable

First and foremost our future freight transportation systems must permit global sourcing. Fifteen to forty percent of the cost of a delivered product pertains to transportation, inventory, and distribution costs. The transportation chain has been replaced by a logistics chain. The rapid advance in information technology have made possible seamless logistics chains. As cargo is becoming lighter and more expensive, it is increasingly important to minimize in transit inventory costs even at the expense of using higher priced, more effective and efficient transportation chains. The transportation officer has become the logistics officer.

6/ Cross-cutting Transportation Issues

Issues which cut across the transportation markets include innovation and research and development, economic growth and competitiveness, accessibility and mobility for the transportation disadvantaged, future energy requirements, national security and environmental considerations.

Slide #9
Transportation Markets

MULTIMODAL MARKETS	CROSS-CUTTING ISSUES					
	Innovation and R&D	Economic Growth & Int'l Competitiveness	Accessibility & Mobility for Disadvantaged	Future Energy Requirements	National Security	Environmental Considerations
INTERCITY PASSENGER						
INTERCITY FREIGHT						
URBAN/ SUBURBAN						
RURAL						

Slide #10
Economic Growth and International Competitiveness

Findings
- Consensus as to the role of transportation is lacking
- Quantification of role of transportation in economic growth
- Need transportation system performance measures
- Congestion projected to worsen and inhibit growth
- Role of transportation barriers in global economic competition

A major message from the outreach seminars on the role of transportation in economic growth and competitiveness was that the public does not fully understand the role and importance of transportation in their lives. In any list of national priorities, transportation is well down the list. The public sees transportation as a free good. If the transportation infrastructure is to be preserved, it is essential to get across the concept that transportation is important in our lives and not just another pork barrel.

To add to the uncertainties about transportation's role in the economy, there are no measures or indicator as to the overall performance of the total transportation system. We need measures of total transportation system performance to better allocate our limited transportation resources, but we don't have them.

There is a continuing concern about the existence of transportation barriers to global economic competition. There was almost universal agreement from transportation carriers and shippers that there was a need for a level playing field; however, there was almost universal disagreement as to which playing field should be leveled.

Slide #11
Transportation and Future Energy Requirements
- Major concerns are petroleum availability, air quality, global warming, and catastrophic spills
- Petroleum scarcity is not a concern
- Strong long-term R&D program is needed to develop non-fossil fuel based technologies

The major transportation-related energy issues currently pertain to petroleum availability rather than petroleum scarcity. The question is no longer do we have enough petroleum but rather where is it located.

The major concerns pertaining to the use of petroleum at present revolve about urban smog, global warming, and the threat of catastrophic spills. In the light of the Alaska oil spill, how big should we build tankers? Should they have double bottoms? Petroleums scarcity is not the major concern.

In the longer term, in areas such as the Los Angeles basin there appears to be a growing consensus that there will be an urgent future need for non-fossil fuel-based transportation systems.

7/ Transportation System Innovation and Research and Development

During this past year as part of the development of the national transportation strategy, numerous discussions have been held on the subject of the role of private and public sector R&D in ensuring continuing transportation system innovation.

There was a strong sense among outreach participants that transportation system innovations leading to major enhancements in the productivity of human and material resources are essential in an era of intense global competition.

Innovation was linked to the nation's ability to ensure jobs and economic security for many Americans. The cost of transporting U.S. goods and services influences America's productivity and ability to compete effectively in domestic and international markets.

A significant distinction was made between research and development and innovation. Research and development is considered as one means for achieving transportation system innovation – but, it is not the only one.

The recent report of the M.I.T. commission on industrial productivity has indicated that in the post war years the United States invested heavily in technology research, and the investment paid off – sometimes in surprising ways. Basic research, undertaken for its own sake, often led to commercial applications that could not have been predicted at the outset. These experiences shaped current expectations for science and technology.

There is no question that investment in basic scientific and engineering research is essential for long-term economic growth. At the same time, the nation's technological strength depends on far more than the strength of its research laboratories. Prowess in research does not lead automatically to commercial success. New ideas must be converted into products and processes that are within the capabilities of the workforce to produce and that customers want.

The United States is still unarguably the leader in basic research. The scale of its scientific enterprise is unequaled. Yet, U.S. companies increasingly find themselves lagging behind their foreign rivals in the commercial exploitation of inventions and discoveries.

It is a long way from an invention to true product or process innovation. Ralph Gomory of IBM recently observed:

Slide #12

"You do not have to be the science leader to be the best consumer of science; you do not have to be the best consumer of science to be the best product manufacturer."

Ralph Gomory, IBM

Innovation is a multifaceted challenge, one that must be met across all fronts. Transportation system innovation must involve financial, operational, and institutional innovations as well as new technologies. Most importantly, innovation must involve the people who are going to use and operate the system.

Slide #13

Transportation System Innovation

- Innovation involves financial operational and institutional as well as technical factors
- Technology, while often involved is seldom the contributing catalyst
- The real foundation and only guarantee of continuing innovation is people.

Innovation is neither a simple nor rapid process. Critical elements include a recognized need, a receptive environment, and hard work. Technology, while often involved, is seldom the controlling catalyst. It was continually noted that people and their willingness to accept change determines when and how innovation occurs.

Slide #14

"There's no silver bullet, no single solution that's going to pull us out of it; but what you see is a lot of little things being proposed, all adding up to creating an environment where innovation can flourish."

Thomas Deen
Transportation Research Board

Comparisons of America to Japan and Western Europe were often cited when seminar and outreach participants suggested a need to "leap frog" existing vehicle technologies as a means to ensure the country's global competitiveness. Constituencies surfaced in support of a variety of advanced technologies. These included proponents of tiltrotor and hypersonic aircraft, high-speed trains and ships, several kinds of magnetically levitated transportation systems and automated highways.

The majority appeared to favor incremental balanced approaches that do not place undue emphasis on untested vehicle technologies in reaction to foreign developments.

Questions were raised concerning the roles of private industry and government in pursuing advanced technologies. A clear answer, however, did not emerge. While most agreed that the risk of basic research is best borne by the Federal government, many asserted that advanced vehicle innovations need to be market oriented. The recent reluctance of industry to develop a hypersonic commercial aircraft was cited as an example.

Over the past five years, the speed, accuracy, and decreasing cost of electronic data sensing, communications, and processing systems have resulted in major innovations in the management of passenger and freight transportation.

Slide #15

Technological Innovation in Transportation 1980-2000

"During the past 30 years, a number of technological innovations, such as diesel and jet engines, have revolutionized the transportation and distribution industries. During the 1980s and 1990s only one development of similar importance is expected: the rapid evolution of computerized information systems."

Ref.: Lewis M. Schneider
"New Era in Transportation Strategy"
Harvard Business Review,
March-April, 1985

Two prime examples of managerial and operational innovation are seamless, just-in-time distribution and computer-based airline reservation systems.

The information-oriented changes in transportation are being drawn by continuing efforts to improve the productivity and the competitive position of domestic companies.

Such technologies are being applied to the Defense Department's logistics activities.

Slide #16

"Greatest gains are not going to be made in the speed or size of ships, trucks, trains, and planes, but in how we control things moving through our system."

General Duane H. Cassidy
U.S. Transportation Command

Much enthusiastic testimony was received in favour of intelligent vehicle highway system technologies to improve the management and operation of future highway and traffic management systems, and in the application of information processing and communications technologies to the development of new processes for infrastructure maintenance and rehabilitation.

The rapid growth in the application of all facets of information technology to transportation system automation has, however, raised serious questions concerning operator underload and overload. Too much information can result in operator boredom and lack of

alternatives for meeting emergencies and, at the same time, it may also impair an individual's decision making responsibilities.

Slide #17

"Automation should be there to help the operator and not replace the operator. Humans with all their fallibility should remain in the system."

Earl L. Wiener
Human Factors Society

"We can't just arbitrarily provide information to people, and we can't provide it too quickly. Humans have certain limitations and we have to deal with these limitations."

Wade Allen
System Technology, Inc.

Slide #18
Changing Perceptions of
Federal Role in Civilian R&D

1970 - 1990

HARDWARE	→	KNOWLEDGE
PRODUCT	→	PROCESS
DEMONSTRATION PROGRAMS	→	AWARENESS OF ISSUES & TRENDS
TECHNOLOGY PUSH	→	MARKET PULL
R & D POLICY	→	INNOVATION POLICY

In response to the question asked by the sponsors of this conference – Will technology enable us to meet the challenges we face in Transportation? The answer is a qualified – Yes.

However, technology is only one factor in bringing about transportation system innovation; equally important are the knowledge, skills, and characteristics of the people who use and operate the system, and the nature of the processes or know-how by which all three elements are brought together.

In the 1970s the federal government invested in a variety of transportation technologies ranging from supersonic aircraft, to high-speed trains and people movers; if you could get to the moon you could certainly take care of moving people and goods here on earth. We were naive. Technology proved to be only one part of the problem of effectively and efficiently moving people and goods.

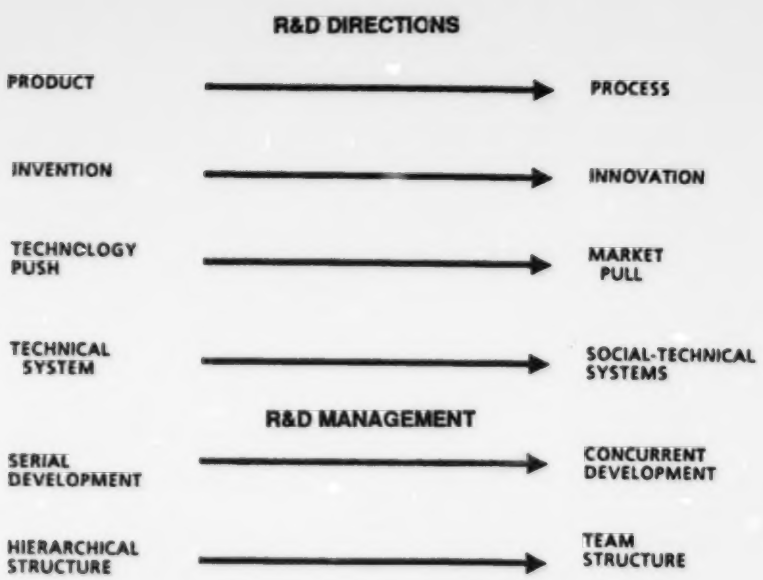
Limited federal R&D transportation dollars, where the government has neither regulatory, safety or operational responsibilities, have become increasingly allocated to:

1/ the generation of knowledge for improved private and public sector decision making;
2/ concern with the transportation process rather than transportation products;
3/ awareness of issues and trends rather than major demonstration projects. Technology push in which the public was shown what they might have was replaced by market pull in which the public was asked what they wanted. R&D policy has been replaced by innovation policy.

8/ Changing Concepts for the Direction and Management of R&D

The concepts for the direction and management of civilian R&D are changing in much the same manner as for federal transportation R&D.

Slide #19
Changing Concepts for
R&D Directions and Management



The management of R&D programs is moving from serial to concurrent development. Rather than moving in a linear fashion from research, to design, to development, to manufacturing, these functions are being handled concurrently. We are moving from hierarchical to team structures.

The current approach to encouraging transportation innovation is to treat technology, human resources, and the process for bringing these elements together as a single system. Processes include administrative and institutional structures. These elements must not be looked at separately but as a whole system. The nexus for transportation system innovation is where these elements come together. We cannot neglect the human no matter how dazzling the technology. The current frontier for transportation system innovation is the human being. How much information can he or she absorb? The human can be underloaded or overloaded with too few or too many inputs. What does the traveller really want? There has been very, very little research in these areas.

9/ Major Themes for the National Transportation Policy

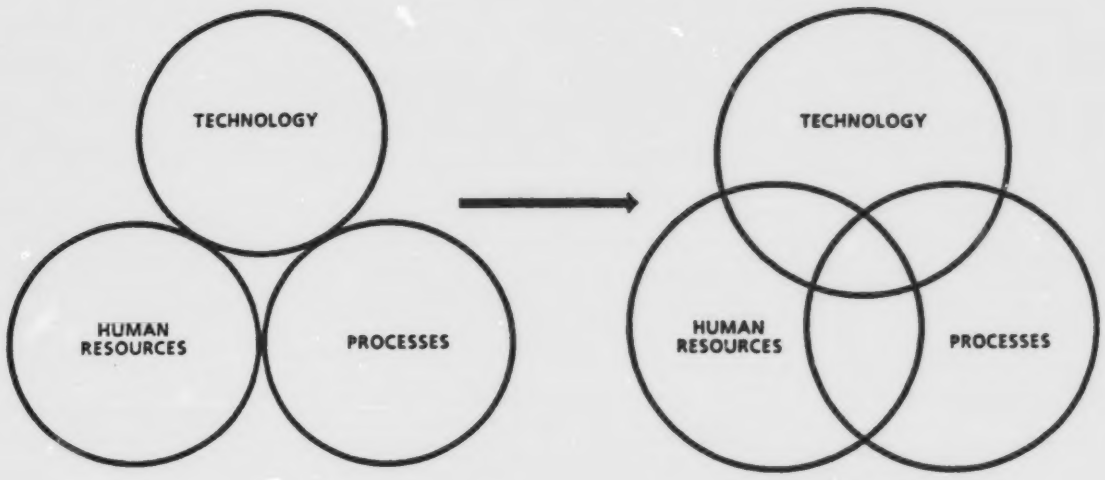
The major themes for the National Transportation Policy are indicated in the following chart.

Slide #21
Major Themes for National Transportation Policy

- Stronger partnership among federal, state, and local governments
- New and creative ways to apply principle of user fees
- Stimulate more private investment in transportation
- Remove unnecessary regulations
- Advance U.S. transportation technology and expertise

Slide # 20

Transportation Systems Innovation



Responsibility for upgrading and maintaining the existing infrastructure will be increasingly shifted to state and local governments, although Federal government will continue to play a significant role. User fees, including toll roads and passenger facility charges at airports are increasingly likely. Strong effects will be made to remove any and all barriers to private infrastructure investment. Efforts will be continued to complete deregulation of the transportation system both at the interstate and intrastate level.

U.S. technology and expertise will be advanced in three areas.

Slide #22

Advance U.S. Technology and Expertise

•Increase federal spending and attention on innovation and technology (new intercity passenger technology, smart cars/smart highway)

• Foster improved transportation education and workforce

There will be increased federal spending for and attention to innovation and technology including encouragement of public/private partnerships for the development of new intercity passenger technology and "smart car/smart highway" systems. In the face of a rapidly changing workforce there is increasing concern about improved transportation education. Finally, in order to create awareness of local, regional and national transportation requirements there will be increased emphasis on improved data collection, and dissemination, planning and decision making.

PROGRAM ON ADVANCED TECHNOLOGY FOR THE HIGHWAY – EMPHASIS ON SAFETY

Robert E. Parsons

Robert Parsons is Director of the Program on Advanced Technology for the Highway (PATH) at the University of California at Berkeley. Mr. Parsons has over 35 years of engineering and R&D experience in industry, government, and academia and is a registered professional engineer in the states of California, Maryland, Ohio, and Nevada.

In almost every traffic poll or congestion study, Los Angeles comes up as the most congested U.S. city. Unfortunately, usually included in the top five cities on these dreaded lists is San Francisco. Another poll (KQED-TV, 1990), for the seventh consecutive year, cited traffic as the San Francisco Bay Area's biggest problem in 1989. Considering that this survey was made within a month of the October earthquake and that traffic concerns still received twice as many votes as the number two issue – earthquake relief – this poll sounds an alarm. It's clear that traffic congestion is a very *big* California issue.

For the last decade, the Los Angeles rate of traffic congestion has been increasing at a staggering 15% per year (Caltrans, 1989). Other key averages included in that study were:

- Increase in vehicle mileage travelled - 5 % per year
- Supply or added highway capacity - 1% per year
- Population growth - 2.5 % per year

Those who deal with traffic management know that the normal traffic engineering tools will not adequately address problems of this magnitude. In fact, some of the recent navigation studies indicate a potential to save about 10-20% at best (Jeffery, 1981) (Kanafani, 1987). Therefore, a bold approach must be taken to attempt to find ways to achieve an order of magnitude change. We need another *big* advance in highway capability similar to that obtained by introduction of the interstate/freeway concepts, which have provided urban traffic congestion relief during the last thirty years.

Fortunately, many things are under way to bring vitality back to the major urban transportation systems in our cities. In traffic management innovations we have the Smart Corridor concept, the PATH-finder demonstration scheduled to begin later this year, and a large effort to design and implement better Traffic Operation Surveillance centres (Caltrans, 1989). In addition, there is work on two light rail and one heavy rail systems and plans for new toll roads in the greater Los Angeles area alone. But even these steps do not appear sufficient to meet the urban transportation challenge of the next century.

The Program on Advanced Technology for the Highway, or PATH, is a joint Caltrans/University of California research effort to evolve a better vehicle/highway system. The key word here is "system," for during the past century the vehicle and the highway have, for the most part, been developed independently. In contrast to the other transportation modes that have a control subsystem to tie the vehicle and road together in a systems concept, there is little in common between today's cars and freeways, except the rubber/asphalt interface, traffic signs/signals and occasional radio reports. We believe it is time to address the system engineering aspects of the highway system. At the Institute of Transportation Studies at Berkeley and the nearby Richmond Field Station, there is much ado to better understand what technologies make sense for these new highway applications and to evaluate the potential performance and socio-economic impacts of implementing high-tech solutions to solve urban traffic problems.

There is a requirement to report back to Congress in early 1992 on our progress, particularly regarding the possibility of installing segments of electrified freeway in a major city, like L.A., that drives the PATH schedule. To assure that the studies, research, and resulting report are not purely academic, several near-term

hardware evaluations are being planned to obtain "real field" data upon which to base the technology and socio-economic forecasts. So as this overview of current PATH activities is presented, please keep in mind that existing or new-term technologies must be assessed. Due to this short reporting deadline, we cannot seriously consider concepts such as totally autonomous vehicles. These more futuristic concepts are many, many years away before they can be safely implemented into commercial highway applications in our cities.

PATH has been conceived as a process to advance the technology of highway transportation across a broad front by applying electronic elements in both the highway and vehicle portions of the system. The objective is to incrementally improve flow, average speeds, air quality, and safety of traffic on typical urban freeways. The basic principal contained in the PATH program approach (Parsons, 1987) is that the AHS should be evolutionary and voluntary from the user's standpoint. It is another PATH goal that vehicle on-board equipment cost be kept approximately comparable to a good sound entertainment system. Even then, the purchasers of new automobiles must be able to perceive readily the added value of any AHS device. The backbone of PATH will be utilization of existing technology, since the program is aimed at relatively near-term solutions to California's most pressing traffic problems. The early phase includes evaluation, test, and demonstration of a few of these proven techniques. Plans are to advance clean propulsion, automation, and navigation technologies to the level of maturity, such that demonstrations in a freeway environment can take place in the mid-1990s, if that appears feasible.

Early PATH study leads one to conclude that safety is the key issue to address. But unfortunately, the public does not perceive safety to be the main problem – they are really hung up in traffic congestion. Activities to address traffic congestion sell politically, so it is the congestion issue that we are addressing. But, as one transportation engineer relating to others, let me tell you, it is clear that we must prevent accidents and incidents, if we are to have any real success in lessening the congestion and resulting air quality problems prevalent in large urban areas. The goal could just as easily have been safety improvement.

Thus safety is the underlying consideration in all our work. In near-term work, we are building upon collision avoidance and traffic smoothing technologies. In the longer term situation, we are studying those technologies that are as close to "fail-safe" as possible. It is clear that the entire concept of applying electronics to roads and cars will hinge on safety (and liability) issues. This is why we plan to engage insurance firms and state and federal safety agencies as partners in our research program.

A highlight of our management approach is to involve experts from other institutions that bring "safety expertise" to the PATH team. For example, we have a railroad controls engineer on loan from the People's Republic of China, a human factors engineer on loan from the French INRETS "Laboratoire Ergonomie Santé Confort" at Lyons, and a noted highway safety expert, formerly with the United Kingdom's Transport Road Research Laboratory, will join us next month.

An overview of the current PATH activities follows:

Most of the PATH work is centred at the university's Richmond Field Station, which is located near the UC Berkeley campus, Oakland, and San Francisco. At this station there is ample building and outdoor space available for construction of test facilities, offices, and research laboratory space for interested industry tenants to co-locate with ITS PATH personnel. We already have two test tracks there.

The near-term PATH R & D activities are of two general types. University research is under way to better understand the feasibility or possible application of advanced technologies to the Los Angeles and San Francisco regions' traffic congestion problems. In parallel, there are field tests or small demonstrations of existing technologies to better understand their capabilities or limitations and to provide more data for the analyses going on in the university, especially those related to performance and safety. Cross fertilization between these two distinct early PATH phases is

stressed. Examples of the work to be supported for the next two to three years follow:

Lateral Control

There are obvious examples that one can envision in which an effective lateral control mechanism could improve the traffic flow through restricted system bottlenecks. There are such systems carrying passengers in Germany and Australia that employ lateral guidance to save space. The Bay Area bridges are probably the most obvious California example of an opportunity to increase vehicle throughput in this manner. Thus, the question is not so much one of technological feasibility, but one of how to introduce an effective, low-cost lateral control system that can be safely implemented on an evolutionary basis.

One of the first assignments of the new PATH team was to assess the state of the art in the applicable technologies. There has been considerable work done in vehicle control work at General Motors (Bender et al., 1982) and at Ohio State University (Fenton, 1981). In addition, researchers made a tour of Japan and Europe (Kanafani et al., 1987) to discuss work and possible co-operative efforts with key researchers at the appropriate organizations. On this trip, the PATH staff were able to ride existing lateral control systems and formed an opinion that current systems would be excessively rough in lateral jerk at freeway speeds and would not be enthusiastically accepted by private car owners. This is caused by a close tolerance control system that provides an immediate steering correction once deviations are sensed relative to the electronic (or physical) reference. Clearly, this task becomes more difficult as speed increases.

Upon their return, this team initiated research aimed at providing preview (road geometry) information to the vehicle. This improved lateral control system, incorporating artificial intelligence so that the controller doesn't need an "as soon as possible" mentality, could, in theory at least, provide smoother transitions and improved ride quality. UC is developing a passive, discrete "smart" marker system wherein the vehicle would sense the marker's presence and obtain lateral orientation plus encoded information relative to upcoming road geometry and other information (Parsons, Zhang, 1987).

Recent development of many passive devices (infrared, acoustic wave, etc.) that utilize a portion of an incoming energy beam to transmit back an encoded message provides attractive marker options. The selection criterion for the initial marker was based primarily on the least expensive approach. Thus, the team at the institute has developed permanent magnet marker sensing (Parsons, 1989) which is now in the early component testing phase. The field of the magnet itself provides lateral reference and close spacing of these magnetic markers will provide a quasi-continuous reference line without the need for any "in-road" energy. This technique has significant safety implications due to the inherent reliability and long-life characteristics of permanent magnets. By strategic positioning of the magnetic poles, binary information can be encoded in a serial fashion to provide messages on upcoming road conditions that can be picked up and interpreted by the vehicle's on-board processor. In essence, a vehicle can be made to look and think ahead similar to how people drive cars. The safety advantage is that weather, heavy traffic, or other obstructions normal in "visual" approaches, are non-problems with this concept.

During the next 18 months, plans call for:

1) selection and/or design of the applicable on-board magnetic sensors
2) investigation of how to use effectively the sensed information
3) design of a controller that makes use of artificial intelligence without too much on-board data processing to provide smooth lateral control.

A major task is to conduct reliability/safety analyses to determine failure modes as they affect hardware design approaches for safety. In parallel, a system safety effort will be initiated to gain a consensus among cognizant safety organizations as to what "safety improvement goals" should be applicable to "electronic assists and/or controls" on future highway vehicles (Shladover, Parsons, 1989). The problem is closely akin to that faced by commercial aviation when collectively the industry accepted the "fly-by-wire"

philosophy that has led to a much improved and safer air system.

After initial low speed testing has been concluded, an assessment of the magnetic marker ability to provide consistently reliable pickup will determine whether high speed tests will be conducted or a more robust discrete marker considered. The UC sensor and actuator centre is working on this latter point. Safety and roadway maintenance costs will be prime considerations.

Longitudinal Control

As was the case with lateral guidance, the first longitudinal control research task is a technical assessment by UC Davis researchers of previous findings in this field and a definition of a performance specification applicable to the goals and objectives of the PATH program. Concurrent with this technology assessment, other parallel efforts are being supported.

One is the design of a field experiment based upon a unique collision avoidance system developed by Radar Control Systems, Inc. (RCS) of San Diego, California. RCS has developed, road tested, and field demonstrated a very interesting concept of using a doppler radar anti-collision warning device to assist drivers in avoiding accidents or incidents (Davis, 1987). This design ties the radar signals to a vehicle's cruise control and braking systems, so that one car may trail another.

PATH, RCS, and Caltrans will conduct simulations to define the response of the combined radar "car following" system and the expected dynamic behaviour of a series of three automobiles provided by the Ford Motor Company. Independently, UC faculty and graduate students will be doing similar simulations on fleets of vehicles to determine what type of vehicle-to-vehicle communication system is required to improve the stability and safety of these platoons.

A large-scale co-operative effort between RCS, Ford Motor Company, Caltrans, the California Highway Patrol, National Highway Transportation Safety Administration, and the PATH team at the University of California is planned to obtain data regarding the car-following concept. These tests will be conducted on the new Interstate I-15 High Occupancy Vehicle lanes with three passenger cars and the RCS data gathering van to collect field data relative to stability of the string and tendencies for small disturbances in the lead vehicle to propagate back through the platoon.

In parallel, a technology assessment of the RCS collision alerting system (no braking or throttle control) will be conducted by a PATH subcontractor to determine the usefulness of this device in an accident avoidance mode. A detailed review of vehicle, radar, and driver reactions to the collision avoidance system signals will be conducted during a four-month, 2500-mile test program, designed to include typical highway situations. Issues to be examined include electronic and weather induced interferences, false alarms, missed targets, and driver convenience/annoyance factors.

After data has been verified, a demonstration specification for a larger car-following experiment is planned to be issued. It is envisioned that a follow-on competitive contract (cost shared) will be awarded to demonstrate the feasibility of platoons of perhaps 15 to 25 vehicles. A vehicle-to-vehicle communication system will probably be an integral part of this larger demonstration.

Non-Contact Electrification

Another aspect of PATH is the study of cleaner propulsion, building on the Santa Barbara Electric Bus, non-contact electrification technology base developed by Systems Control Technology, Inc. of Palo Alto, California (Shladover, 1988). A dynamic, electrified test facility was constructed at the University's Richmond Field Station and tests are in progress to evaluate the hardware and obtain measured performance data.

A second generation, on-board power control system has been installed on the prototype bus and the test track features two 200-foot powered sections. Loop detectors provide for automatic control of the supply of power to each segment of track for a duty cycle representing the Santa Barbara bus application. The performance of all the components and subsystems needed to effect the power transfer to the moving electric vehicle will be tested.

The PATH success is not contingent upon this propulsive means, but since California leads in this field and many feel that an eventual AHS system must employ a cleaner and more dependable propulsion system, the program will build on this base and utilize existing hardware to ease the cost of entry into other AHS component evaluation/testing.

In pursuit of cleaner propulsion alternatives, PATH and Chevron Research Company have engaged many interested organizations to review other promising, near-term cleaner alternatives to today's conventional internal combustion engines and present fuels. This group is seriously considering ways to assess systematically, and perhaps test, a series of hybrid power drives that offer alternatives that may be socially acceptable in non-complying "air quality" areas such as Los Angeles and San Francisco.

Concurrently, the Southern California Association of Governments has been assisting the university by conducting a highway electrification and automation impact study in the six-county Los Angeles region. Costs and benefits will be addressed and environmental, safety, mobility, and energy issues will be evaluated.

Another impact study is planned to determine the feasibility of roadway electrification and selected automation for electric buses in a busway/HOV application.

Together with the other PATH-supported work, the results of these two major impact studies will provide the support for the 1992 report to Congress.

Navigation

Direction in the navigation area hinges, to a large degree, on the jurisdictional role of the different governmental agencies in the traffic control operation. This issue is significant, particularly in large regional areas where strategic and tactical traffic information/control data must be issued from the central controlling source to be effective. Unlike aviation, responsibility and authority for central operating control are not defined in the highway network.

There is a worldwide emergence of on-board navigation equipment that perhaps will be offered to auto buyers in the next few years. To be most effective, these navigation devices will probably be tied into an area wide traffic control system. In fact, one California company, Etak (Dial, 1987) aleady has one such device available for commercial sale.

Previous studies (Yumoto et al., 1979) (Jeffery, 1981) suggest network travel time savings of perhaps 15% can be obtained by providing better real-time information to vehicle drivers. Continued interest prevails, especially if larger gains may be realized by better management of the system, and at present there are three demonstrations planned for the 1989-90 time frame in West Berlin, London, and Los Angeles. The safety improvements to be gained by these "real time" information systems have yet to be assessed. It may be found that by providing timely advisory information to drivers, many will avoid incident and accident scenes and thus, rear-end crashes can be avoided.

The Los Angeles "PATHfinder" experiment is smaller in scale than the others and is tailored to the California urban freeway situation. A 12-mile section of the Santa Monica freeway west of Los Angeles known as the "smart corridor" will be extensively instrumented as will parallel arterials in this "test section."

Plans call for some 25 General Motors donated vehicles equipped with Etak navigators to be driven by approximately 400 individual test drivers during the one-year test. The purpose of the large number of drivers is to remove the familiarity aspect of driver/navigator and also to provide a statistically valid database for assessment purposes. This experiment design aims to answer questions such as:

1/ the value of a dumb (no real-time data) navigator,
2/ the value added by "smart" navigators which know the whereabouts of incidents and anticipated delays in the network,
3/ the value of using navigator equipped vehicles as traffic flow meters for central traffic monitoring/control.

The first several PATH papers were an assessment of the previous work and state-of-the-art and navigator

equipment per se and suggested research topics (Kanafani, 1987, Gosling, 1987). In addition, an initial simulation of the Pathfinder test section was conducted (Al-Deek, et al., 1988) and data was forwarded to those concerned with the framing of the eventual Pathfinder experiments. These studies have identified areas requiring future improvement and the near-term PATH R&D in this effort will address the following;

1) Large-Scale Network Flow Management – Simulations of traffic control concepts for a large-scale regional area, including use of artificial intelligence, will lead to development of strategic and tactical methodologies to provide guidance and control to platoons of vehicles in key corridors. In parallel, other analyses will address the effect on user/system management benefits due to the nature, scale, and geometry/ environment of the traffic network.

2) Pathnet (Al-Deek et al., 1988) improvements to provide real-time traffic information to drivers and means to handle freeway diversions (arterial control strategies) to gain better overall utilization of the network.

3) Working with drivers of the "Pathfinder" demonstration, experiments and/or simulations will be conducted to determine the optimal type and method of presentation of route guidance/control information.

Conclusion

California urban congestion is very bad and will worsen. It is and will continue to have adverse impacts on the economy, environment, and health and safety of urban residents and commuters. The encouraging news is that the state recognizes that a bold, major breakthrough must be found to reverse this traffic stranglehold on society and has funded a Caltrans and University of California research activity, along with larger capital improvement efforts to address this need.

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TECHNOLOGY OF VEHICLES AND HIGHWAYS

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I'd like to start with a set of compliments to the Ontario Ministry of Transportation. You are to be complimented for your vision in recognizing technology as one of the tools in meeting your responsibilities and objectives. You are to be complimented for your innovation, as represented by the exhibits, in applying technology to a broad range of present and future needs. And you are to be complimented for your wisdom in planning and scheduling this conference, because 1990 is going to be a landmark year in advanced technology for transportation, not just in North America, but across the world.

Now we in North America are blessed with an absolutely fine transportation system. We move more people and freight more kilometres with greater efficiency and safety than anywhere else on earth. And still, we're concerned about congestion and the implications that that has for environmental quality, for highway and traffic safety, and for energy consumption.

We've had an increasing awareness that the conventional approaches to satisfying supply-side requirements and transportation are just not sufficient. That is, building new facilities, making better use of existing facilities, increasing the usage of public transportation or transit, longer-range approaches in terms of land use and life-styles, and finally, the negative implications of controls on the demand side. The fact is that it'll be difficult, if not impossible, to persuade people to stop travelling or to accept controls in the form of tolls or congestion pricing or limitations on where they can go and when they can go to meet their travel requirements.

But fortunately while all of this has been happening there's been an increasing recognition of the role that technology might play in all of this. Dick John quoted the statistics. We're presently losing over $75 billion a year in congestion-related delays for non-commercial vehicles and, perhaps more significantly, we forecast an increase of 435% in congestion by the year 2000.

Well, where do we stand on advanced technology, smart vehicles for smart transportation facilities? It's helpful to start with the definition. We see intelligent vehicle highway systems as technological developments which improve highway safety, operating efficiency, environmental quality, and energy utilization through improved interactions between vehicles, the highways, and the drivers. And by vehicles, we mean not only automobiles, but trucks and buses and other forms of ground transportation. And we see in this a win-win situation, that is, we see something in it for everyone and for society overall.

As a few examples, they range all the way from current work in advanced traffic controls, through ongoing work in the application of the information from the traffic management centres, to motorist information services. And in a set of commercial vehicle operations and advanced vehicle controls, the applications of technology, the features and devices, like head-up displays, near-obstacle detection systems, headway control, a vision enhancement using a whole set of tools. Just as a few examples: microwave, laser radar, infrared, advanced communications command and control, applied in perhaps new and different ways, eventually leading to computer vision applications of lane detection and lane following, obstacle detection, and collision avoidance. And at some point in the next century, the possibility of automated chauffeuring and automated highways. Despite what Dick John said about the 75-year-old man and the information overload, the human factors and industrial engineering aspects are one of the key elements in the research and development program efforts.

At General Motors we have activities under way in all of these subject areas. We think we are ideally suited to work in intelligent vehicle highway systems, because of the vertical integration that we have all the way from the advanced command and control of electronics capabilities of the Hughes Aircraft Company, the computer and data management capabilities of the Electronic Data Systems Group, the volume production capabilities of the Delco Electronics Corporation, the experience in technical abilities of the Technical Staff's Group, and I'll try to say a little bit more about that, and then finally the advanced vehicle design, development, production, manufacture, sales and service, and the commitment of the operating parts of the organization in this important subject area.

As a few examples of the work that's under way: At the Technical Staff's Group, the longer range research and development arm of the organization, at the GM advanced engineering staff, we have work under way in reconfigurable displays, motorist information and communication services, radar applications in adaptive cruise control, and infrared applications in vision enhancement. At the research laboratories, work in what's called the highway driver's assistance and lane detection and lane following using, again, computer vision approaches; work in navigational age in communications as represented by the PATH-finder project in California, and I'll say a bit more about that in a moment; human factors work in dashboard displays. What is it that the operators of vehicles want in the way of information, what do they need, and what are the best ways of providing that information, given the concern about the attention required to the driving task itself?

In autonomous mobility, we're talking about applications of manufacturing, applications in computer vision and robotics now to operation in the real world on the transportation networks of the nation. At the GM Hughes electronics activities, within Delco Electronics itself, we have plans under way for the introduction of a navigation package based on the ETAK navigator in a production vehicle in the reasonably near future, called NAVO car.

There's also work going on in two-frequency doppler radar in near obstacle detection systems, and work in head-up displays, where we now have a production version available in the Oldsmobile Cutlass Supreme and the Pontiac Grand Prix. At the Hughes Aircraft Company, recent work started in the area of co-operative highway studies. Hughes is interested in becoming involved in applying their knowledge and experience in advanced traffic management areas. And to that end, they have been working with some of the more traditional suppliers of systems engineering, analyses and program development in the traffic engineering arena. And if you haven't talked to the Hughes people, I think it's well worth your time to seek out the possibility of co-operative activities. They're active in the development of the new air traffic control system for Canada and, through that means, it's likely that they would be strongly interested in other possibilities as well.

They're also working in areas of advanced head-up and virtual image displays, colour projections. They have a driving simulator. At the Electronic Data Systems, EDS activity, they've been working in areas of fleet management proposals, for example, in the use of a communications advanced vehicle location and identification for emergency vehicles, ambulances, police cars, fire engines, and things of that sort.

Now I'm going to skip very quickly through a set of examples of the work that's under way. The background material to these is given in a paper I presented last year to the Association of Electronic Technology for Automotive Traffic and Driving in Japan. And then if you need additional information, please call me and I'll be happy to supply it. [Note: This paper is reproduced in the appendix of these proceeding.]

But in looking now to the future, both the short run and the long run, we have work under way in the near-obstacle detection systems that I mentioned, in this case, radar applications for looking immediately behind the vehicle and providing an alert and a warning for the detection of obstacles. Clearly, that can be expanded for enhancing the mirrors and blind-spot detection for lane changing or passing manoeuvres. This is a so-called visibility enhancement van, which carries a television and multiple near-obstacle detection systems. These are the TV cameras located both in the

front and the rear with a near-obstacle detection system. This is the display above the windshield, which shows the mirror enhancement on either side of the vehicle, and a printout, a distance measure with regard to a following vehicle.

The head-up displays give a safety advantage, we think, in giving a digital speed readout, turn signal indication, high-beam headlamp, low-fuel warning. All of it in a projection up into the windshield, so the image appears so it's out just over the front bumper of the vehicle. The safety advantage comes in the fact that the operator doesn't have to move their eyes from the road, down to the dashboard, and refocus in the process. And I agree with Dick John that as we have an aging population, vision enhancement of this sort and others is going to be important in the highway and safety arena.

Perhaps the most spectacular of the work under way is vision enhancement. I have a video tape with me and if we can find a suitable projector, we can take a look at it later. But in this case, infrared picking up on the heat allowing a driver to see six to eight times farther down the road in bad weather or night time and distinguish potential obstacles and ways of avoiding those obstacles.

Work in on-board navigation and communications, the ability to portray on a computer screen in the vehicle the current position relative to the intended destination and the direction and distance to that destination. A variety of technologies can be applied here. Satellite-based systems, radio beacon systems, or dead reckoning matchings systems, or a combination of the above. While at the same time, this is a view of a current vehicle installation that we showed in the Trans-Expo, the Exposition sponsored by the U.S. Department of Transportation in Washington D.C. in January.

At the same time, work is going on in advanced traffic control, where information being received on highway sensors, and from individual vehicles, is being used to adjust traffic signal timing and changeable message signs, freeway ramp controls, advising drivers as close to real time as possible with regard to needed information and advice on alternate routes. But clearly if we can tie those now together, the traffic control centre and the vehicle navigation and communications capability, with improved real-time information, then we can demonstrate, we think, real advantage and benefits in motorist information services.

We have a chicken-and-egg situation here in that for the public authorities to make the necessary investment to provide the capabilities for systems of this kind, they need to be persuaded that manufacturers are going to be making the equipment available. And for the manufacturers to make the decisions on the risk and the investments involved, they need to be assured that the facilities are going to be available. And the solution to the dilemma is for us to work together in experiments and demonstrations such as this one in California.

They're building on the so-called smart corridor, Santa Monica corridor, where extensive instrumentation is provided in the road network. We're going to operate a fleet of 25 vehicles equipped with navigation and communications, operating so that as the traffic flow moves along the Santa Monica Freeway between the ocean and downtown Los Angeles, a distance of about 20 km. In a corridor about 4 km wide, we have other, five other, parallel arterial streets, through which traffic can be off-loaded.

Beginning in late April, we'll start operating those vehicles co-operatively between the federal highway administration, the California Department of Transportation, General Motors, and a contractor on a $1.65 million project. The first year of the experimental phase will involve first loaning those 25 vehicles to employees of Caltrans that use that corridor each day for either commuting or business purposes. It's a kind of a shakedown phase. Then in the second phase, we will hire drivers to operate the vehicles in triplets from given origins to given destinations at different times of the day, so that direct comparisons can be made to the advantages gained in terms of travel efficiency, accident experience, and just plain human factors-type considerations. Whether you have the map information, the optimal route guidance in total, or just the map information, or no additional information whatsoever beyond what you can from the A.M/F.M. radio and

changeable message signs, benefits information, we think, for the first time.

We're also going on from there in looking for other co-operative efforts or partnerships in other geographic areas in expansions of the advanced driver systems concept. And we will be making a public announcement we hope in late April or early May with regard to another city in the United States, where we will expand from a corridor to an entire metropolitan area, and from simple optimal trip routing in traffic information, to services and accommodations and yellow pages and emergency road service, in weather, in everything. Again, in a partnership between government at the federal and state levels, and in industry.

Now, given that capability, you can go on to a variety of other menu enhancements, which I suggested. And there are present justifications, economic justifications, for applications in commercial vehicle operations. And, as you know, there are a number of nationwide truck carriers, truckload carriers, instrumenting their tractors with automatic vehicle identification, communications for fleet management purposes to gain an advantage over their competition, relative to the use of their fleet and the identification of business opportunities.

Interaction, collision warning, and collision avoidance using both radar and computer vision approaches. The collision avoidance, as a next step, and then, ultimately, the automated guided highway systems.

Let me close with a few comments about what we see as something that is very much needed in this overall process. We think that for the reasons I mentioned earlier, there is a need for a broad national initiative involving government at all levels -- federal, state, and local -- the automobile industry, but other industry as well, computer electronics and communications industries, and the intellectual prowess and capabilities and interest of the universities and technical institutes.

There is a definite need for benefit-cost data. Early on, and where I have been preaching this for several years, Mobility 2000, an *ad hoc* informal group, has addressed that question in some detail and at their meeting in Dallas later this month, March 19 to 21, they will address both the research and development agenda and a first cut at what the benefits and possible costs might be.

As a follow-on to the Mobility 2000 Conference, there will be a meeting in Florida May 3rd through 5th, a national leadership conference where officer-level people from government, industry, and the universities will begin talking about policy and organization and how much money is required and where that money might come from. It's one of the reasons why I think that 1990 will be a landmark year in this important subject area.

The questions, which technologies, how might we go about reducing the cost, how might we apply the knowledge which has already been gained over time in areas like traffic flow theory and traffic dynamics and experts systems and artificial intelligence, can all be addressed. But beyond that, the expansion of those efforts to not only a North American perspective, but an international perspective. We talk about level playing fields, but if we go in with the attitude that we're going to enter with a team from our national basketball association and the rest of them are going to come in with a secondary school basketball team that's never really played the game before, I think we're being very short-sighted. Instead, we have a lot to bring to the table in terms of past experience and capability. In fact, I think we're *ahead* technically from what's going on in Europe and Japan. But it's embarrassing to see that we're behind organizationally. And we need to do something about that. Clearly, the advantages are going to accrue to the organizations and the people who have addressed the complex and difficult subjects and, if you will, paid their dues. And it seems to me that the Ontario Ministry of Transportation, in your past present and future programs, is well positioned to take advantage of the opportunities that will be coming very shortly.

Comfortable **Convenient** **Efficient** **Reliable**

Affordable **Responsive** **Speedy** **Private** **Safe**

Fun **Stylish** **Flexible** **Quiet**

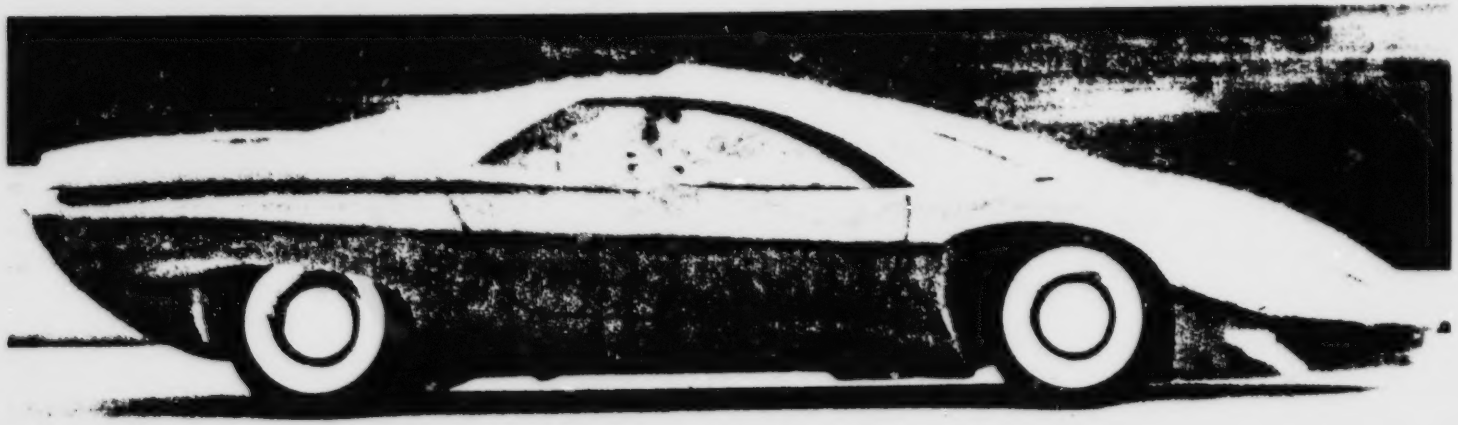


Figure 1

ELECTRONICS USED IN TODAY'S CARS

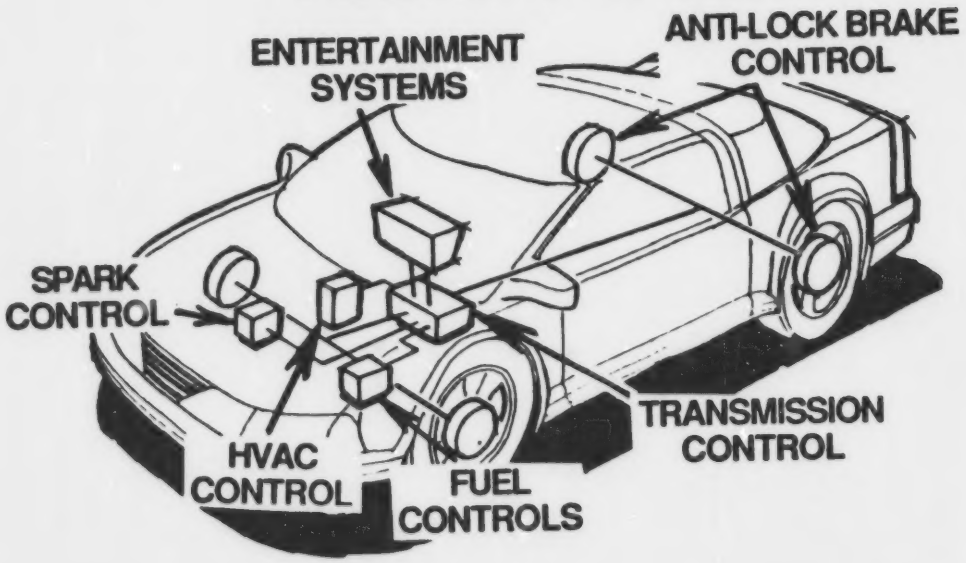


Figure 2

LIMITED WHEEL SLIP DURING DRIVING, BRAKING, AND ACCELERATION

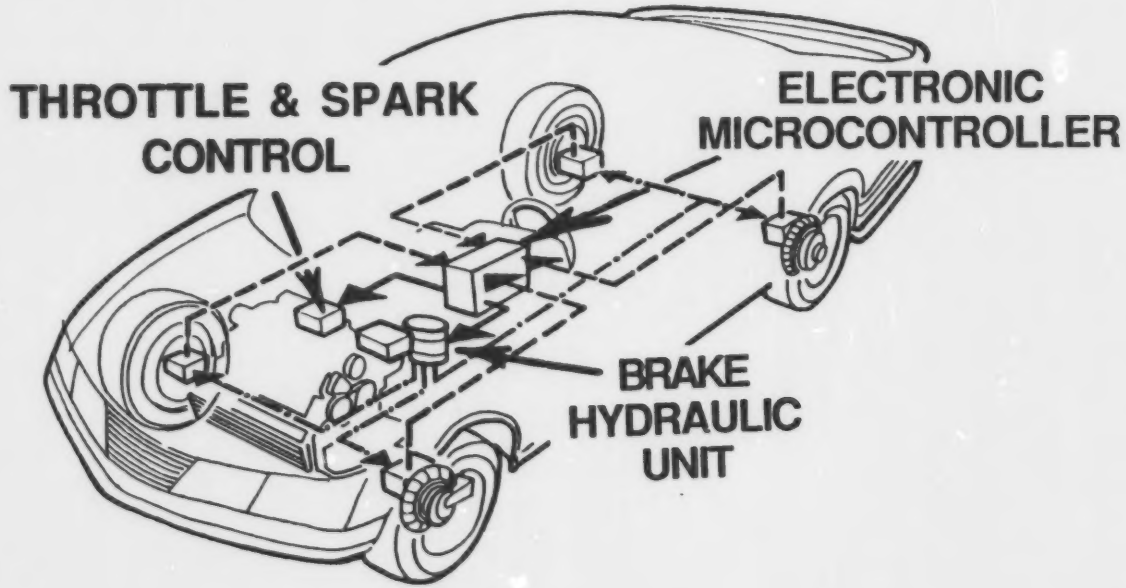


Figure 3

ALL-WHEEL DRIVE

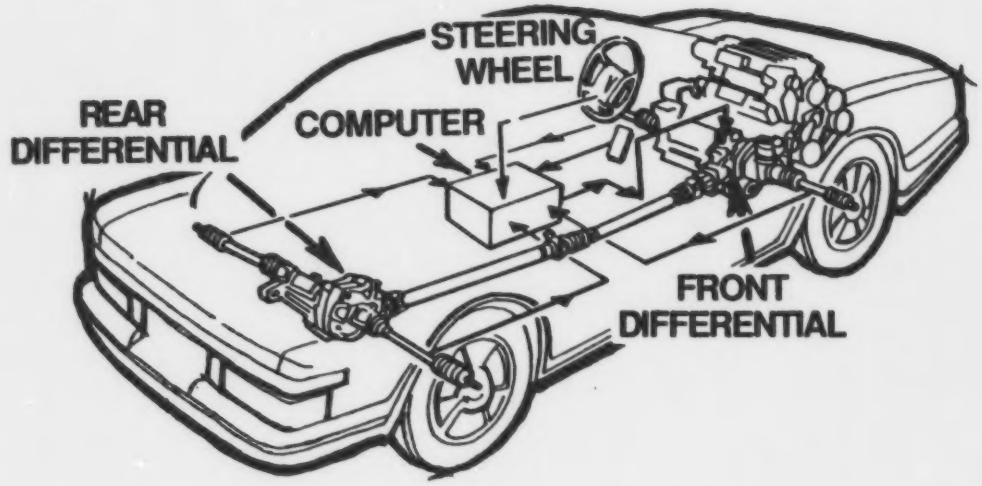


Figure 4

FOUR WHEEL STEERING

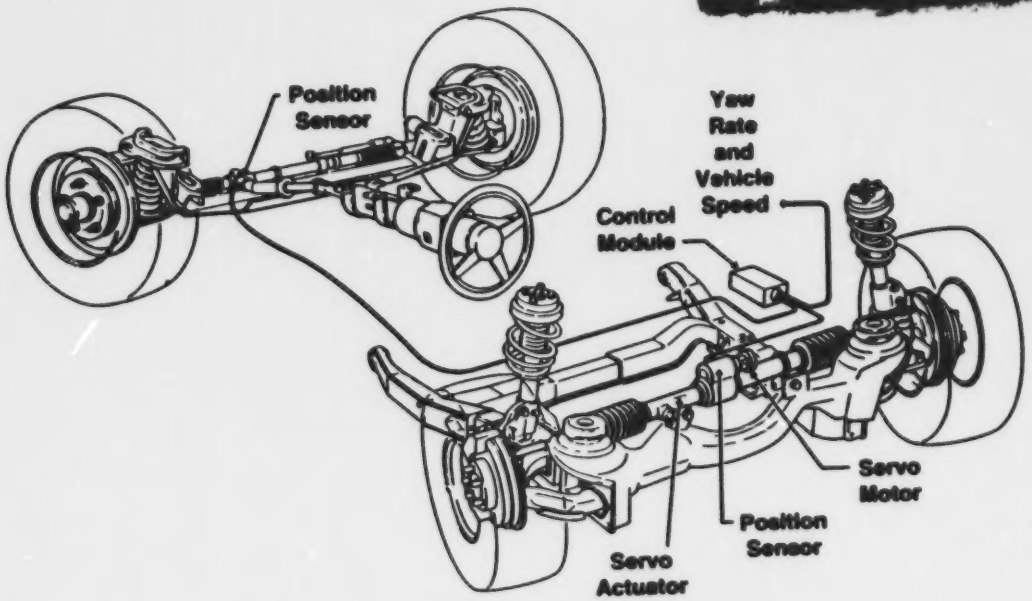


Figure 5

ACTIVE SUSPENSIONS

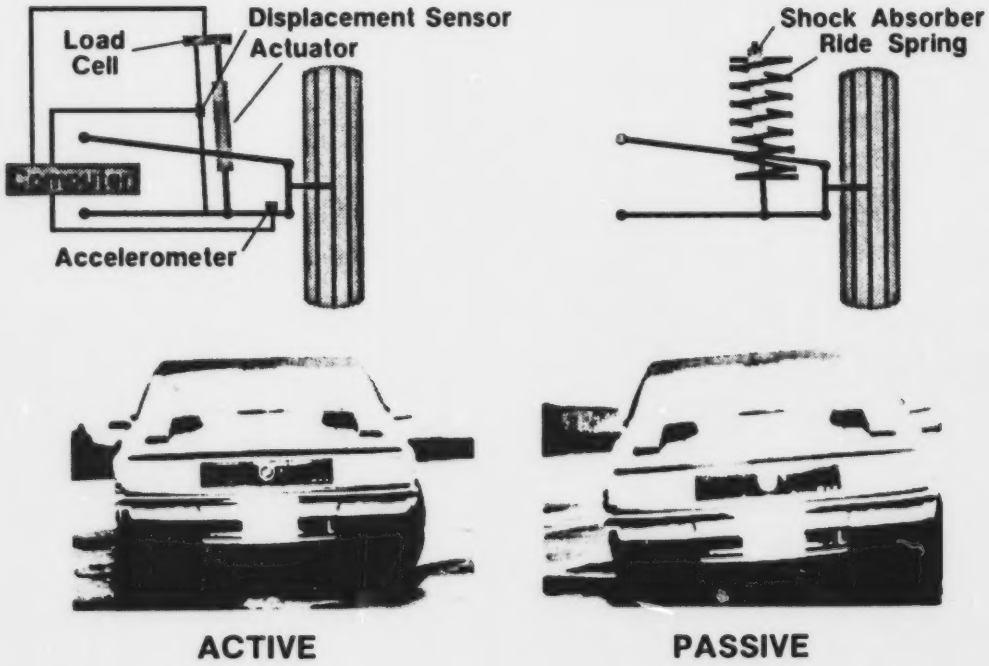


Figure 6

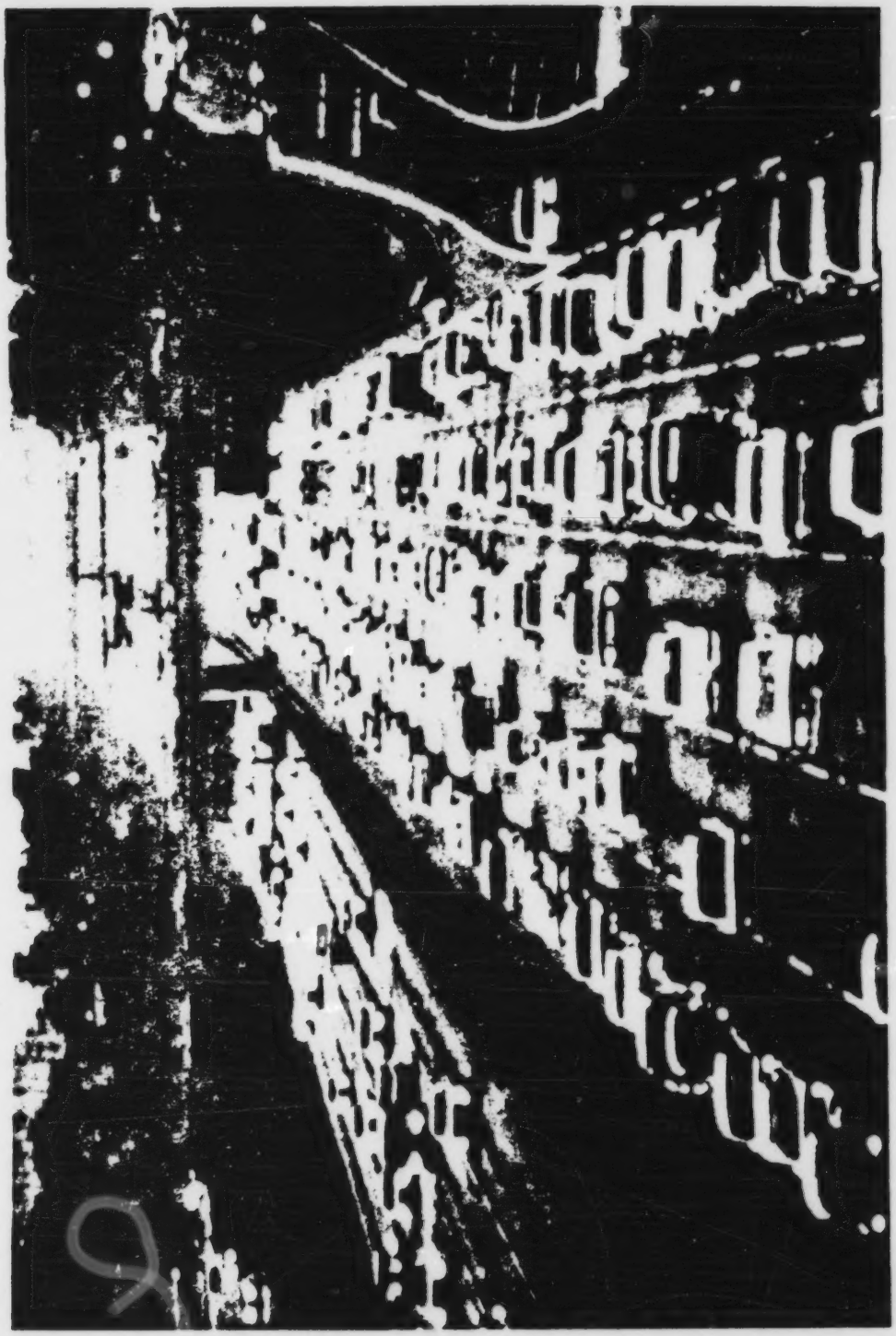


Figure 7

TRAFFIC CONGESTION

110 Million Commuters in U.S., Doubled Since 1950

1.78 Trillion Miles Driven in 1986, in all Directions

2 Billion Vehicle Hours of Delay per Year

73 Billion $ Loss, Non-Commercial Vehicles, Navigation Errors and Congestion, Large and Small Cities

Expected 400% Increase in Delays by Year 2000

Figure 8

Definition of IVHS

Intelligent Vehicle/Highway Systems are technological developments which improve

- Highway safety
- Operating efficiency
- Environmental quality and
- Energy utilization

through improved interactions between

- Roads
- Vehicles and
- Drivers

Figure 9

Examples of IVHS

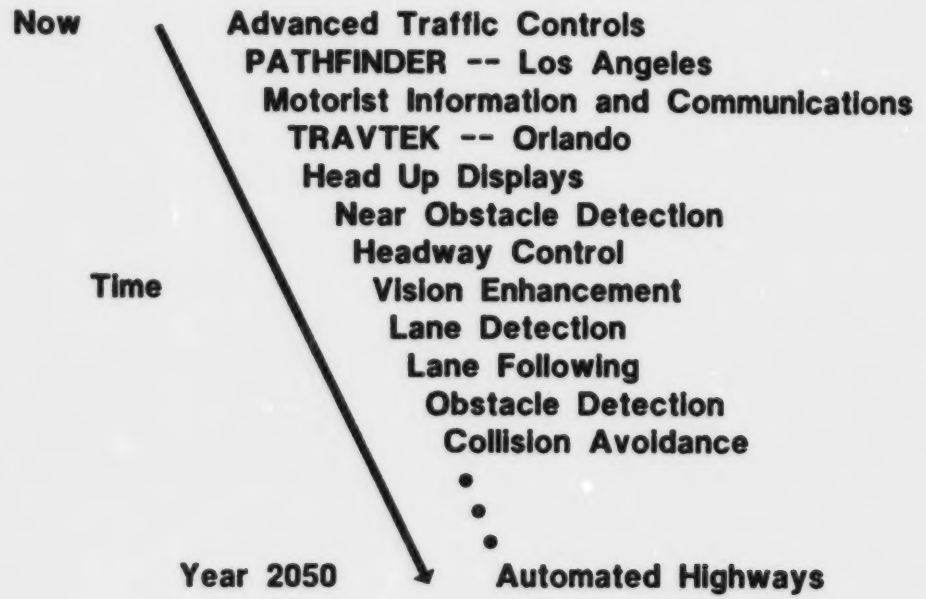
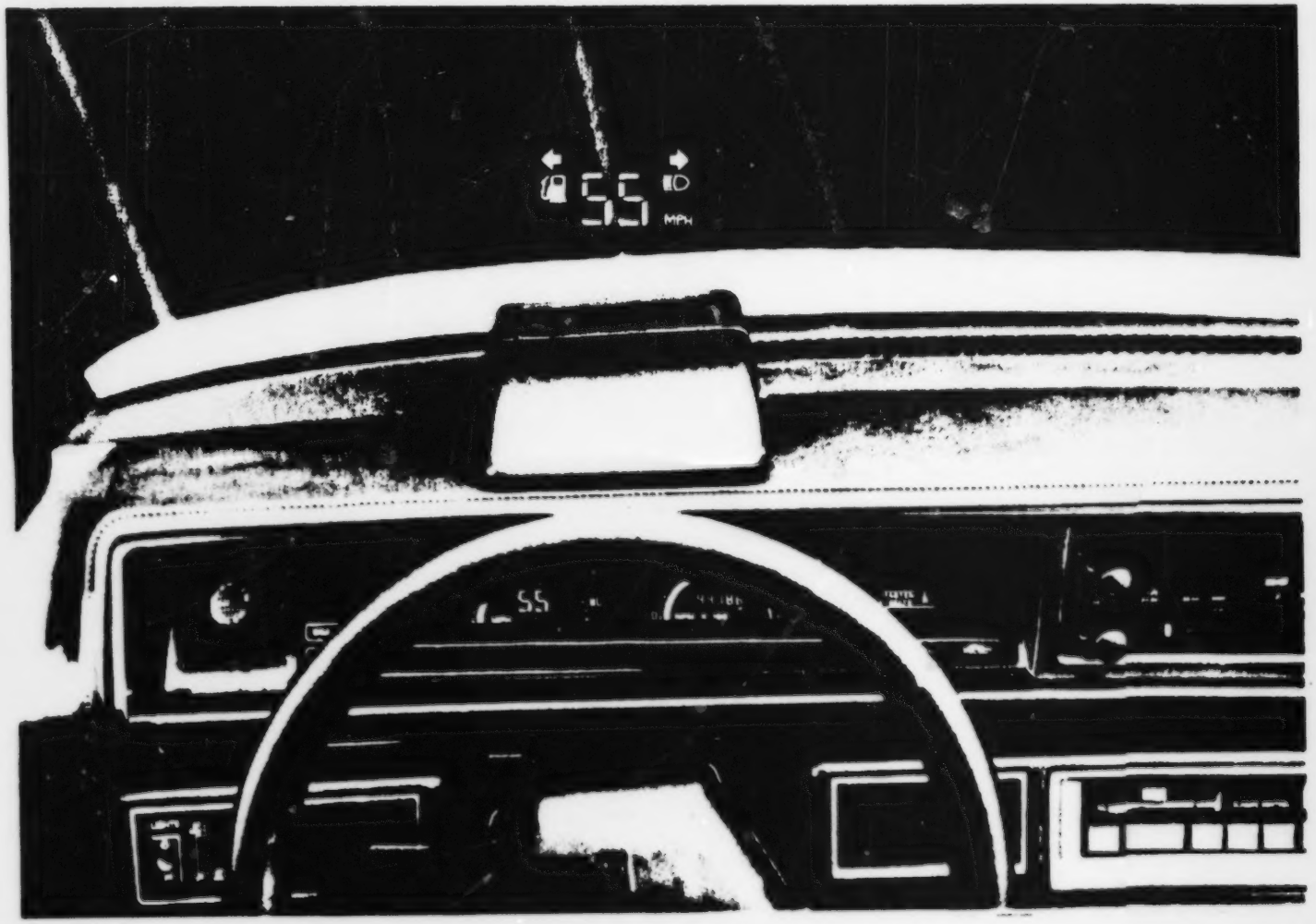


Figure 10

GM Programs

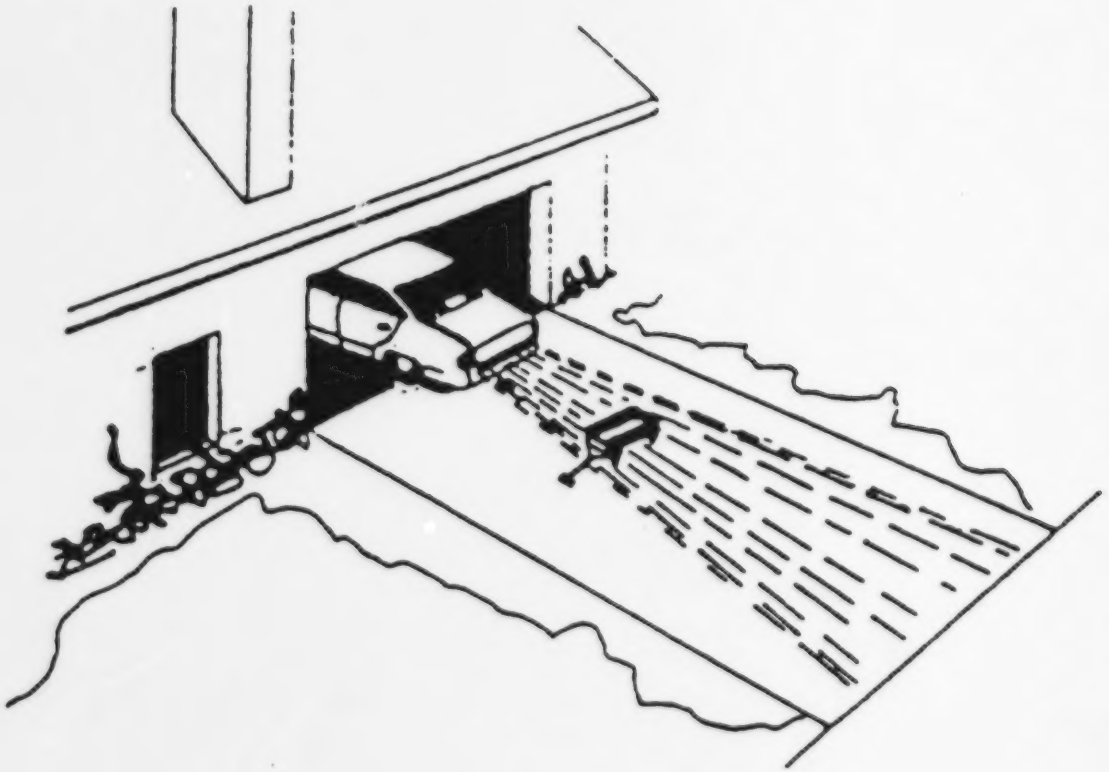
- TECHNICAL STAFFS GROUP
  - GM Advanced Engineering Staff
    - Reconfigurable Displays
    - Travel/Business Information
    - Adaptive Cruise Control
    - Vision Enhancement
  - GM Research Laboratories
    - Highway Drivers Assistant
    - Navigational Aids
      - PATHFINDER
    - Dashboard Displays
    - Autonomous Mobility
- GMHE
  - Delco Electronics
    - ETAK Navigator (NAVICAR)
    - Near Obstacle Detection Systems
    - Head-Up Displays
  - Hughes Aircraft
    - Cooperative Highway Study
    - Advanced Head-Up and Virtual Image Display
    - Color Projection Display
- EDS
  - Fleet Management Proposals

Figure 11



1988 CUTLASS SUPREME INDY 500 PACE CAR HEAD-UP DISPLAY

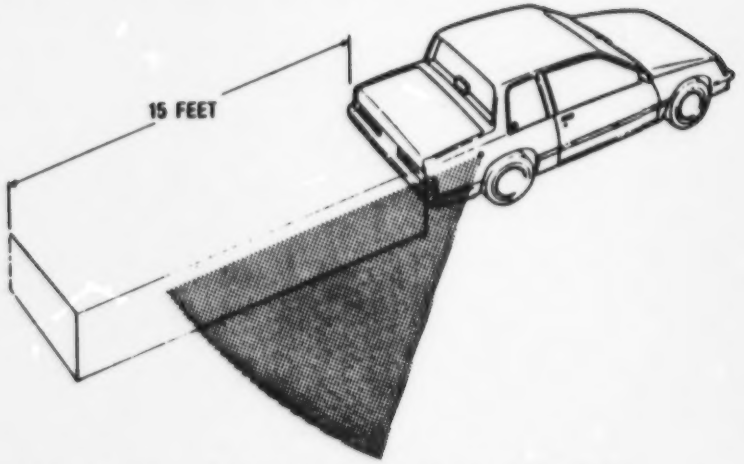
Figure 12



Delco Electronics Near Obstacle Detection System (NODS)

Figure 13

REAR PROXIMITY WARNING SYSTEM:



System will aid the driver during lane changes. The system is activated when the transmission is in a forward gear and the turn signal is engaged. Objects in the driver's "blind spot" are detected.

Figure 14

GM Truck and Bus/Delco Electronics Vision Enhancement Van (VEV)

Figure 15

VEV Video Installation

Figure 16

VEV Liquid Crystal Displays (LCD's)

Figure 17

NIGHT VISION AID

PHOTOGRAPH IN WOODS

INFRARED IMAGE

Figure 18

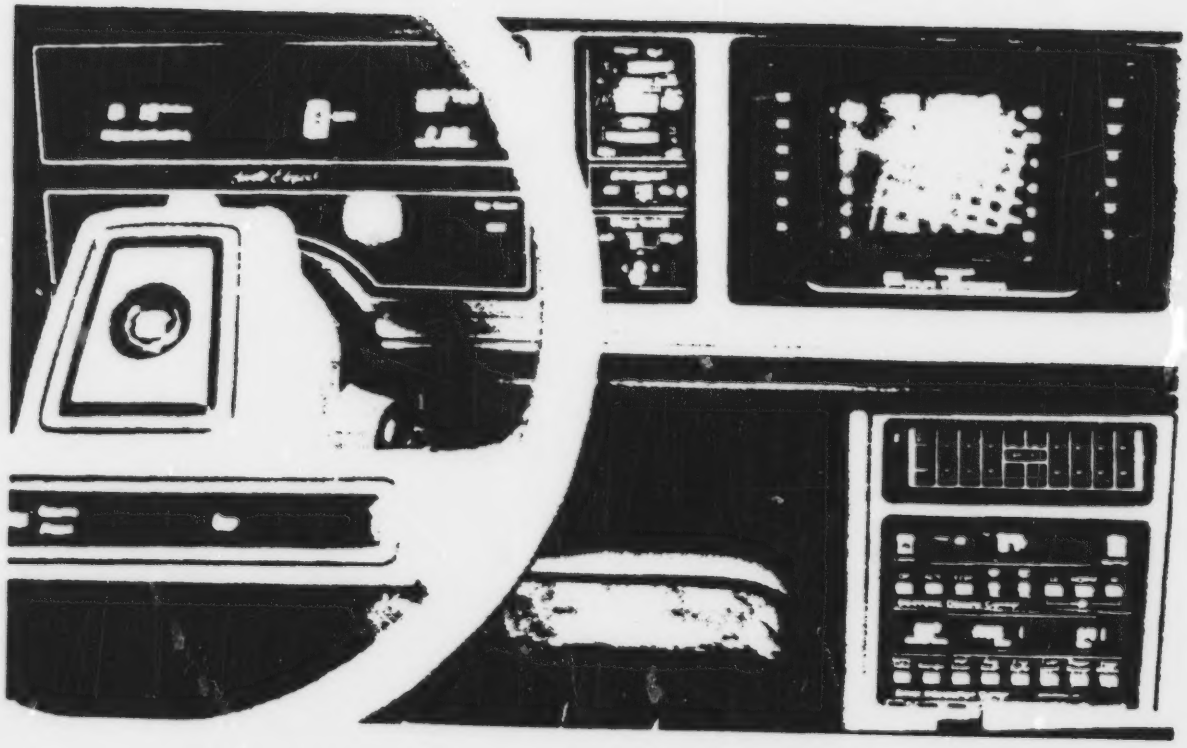
ON-BOARD NAVIGATION SYSTEM

Electronic Map on TV Screen

Shows Immediate Location
- **By Dead Reckoning**
- **By Satellite**

Shows Destination (Specified by Driver)
- **Direction to Destination**
- **Distance to Destination**

Figure 19



General Motors Motorist Information Services (MIS) Display

Figure 20

TRAFFIC CONTROL CENTER

Receives Information from:
- **Highway Sensors**
- **Individual Vehicles**

Adjusts Traffic Signals, Signs, Ramp Gates

Advises Drivers of Road Conditions in Real Time
- **Traffic Density**
- **Snow, Ice, Fog, Rain**
- **Accidents**
- **Construction**
- **Other Blockage**

Advises Drivers of Alternate Routes
- **Artificial Intelligence/Expert System**
- **Traffic Flow Theory**
- **Balances Traffic Density**

Figure 21

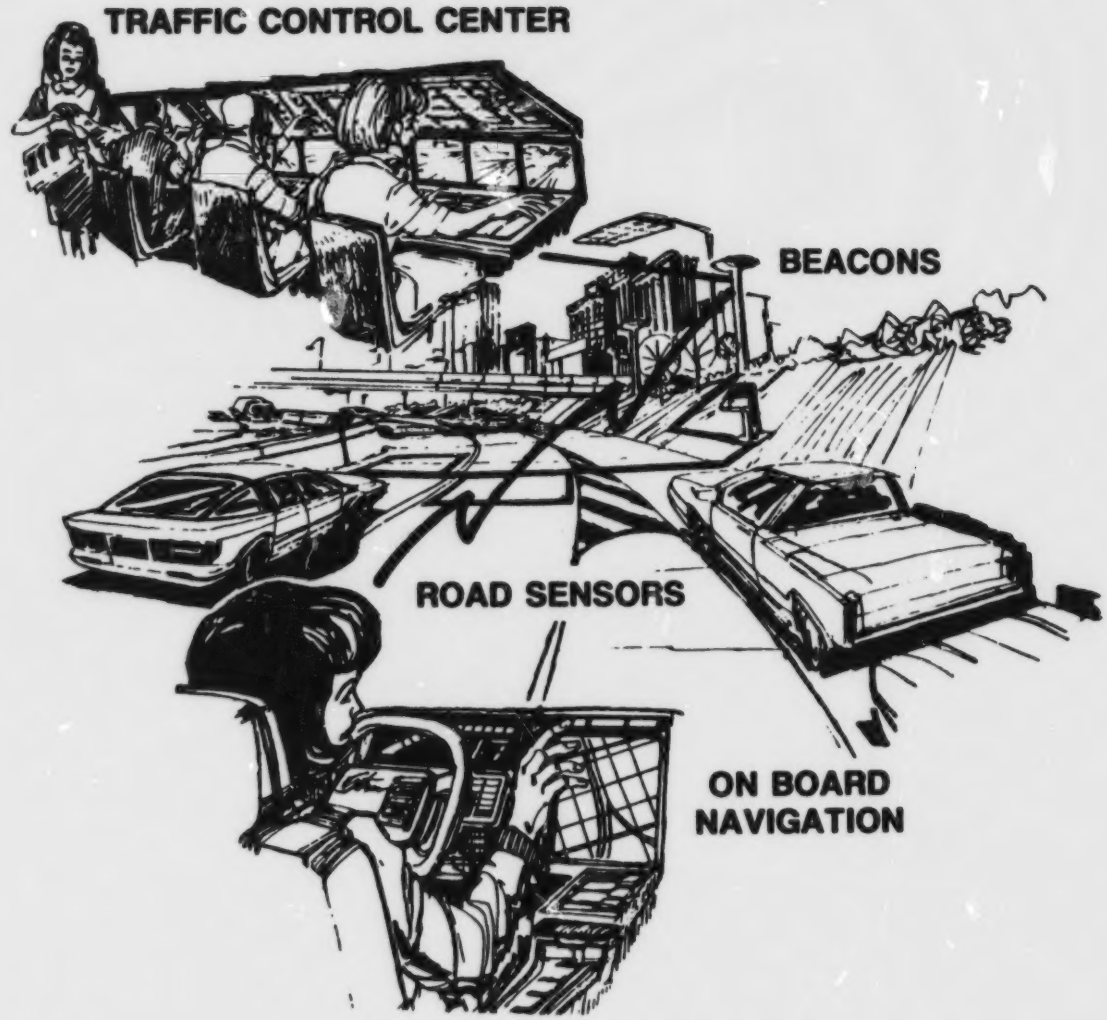

TRAFFIC CONTROL CENTER
BEACONS
ROAD SENSORS
ON BOARD
NAVIGATION

Figure 22

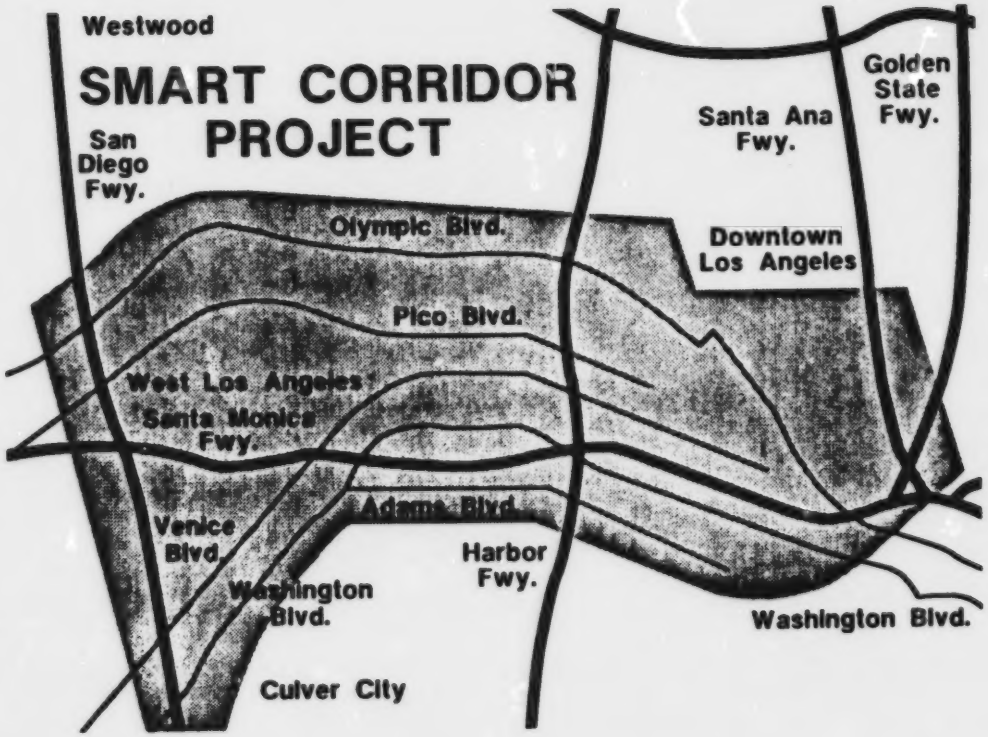

Westwood
SMART CORRIDOR PROJECT
San Diego Fwy.
Olympic Blvd.
Santa Ana Fwy.
Golden State Fwy.
Downtown Los Angeles
Pico Blvd.
West Los Angeles
Santa Monica Fwy.
Adams Blvd.
Venice Blvd.
Harbor Fwy.
Washington Blvd.
Washington Blvd.
Culver City

Figure 23

MENU SYSTEM ENHANCEMENTS

- Parking Lot Locations, How Full, Prices
- Police Station Locations
- Service Station Locations
- Tourist Information
  - Local Attractions
  - Scenic Wonders
  - Historical Information
  - Area Description, Crops, Industries
- Yellow Pages Information
  - Motels, Hotels
  - Restaurants, Menus, Prices
  - Retail Service Locations

Figure 24

TRUCK FLEETS — VEHICLE LOCATION

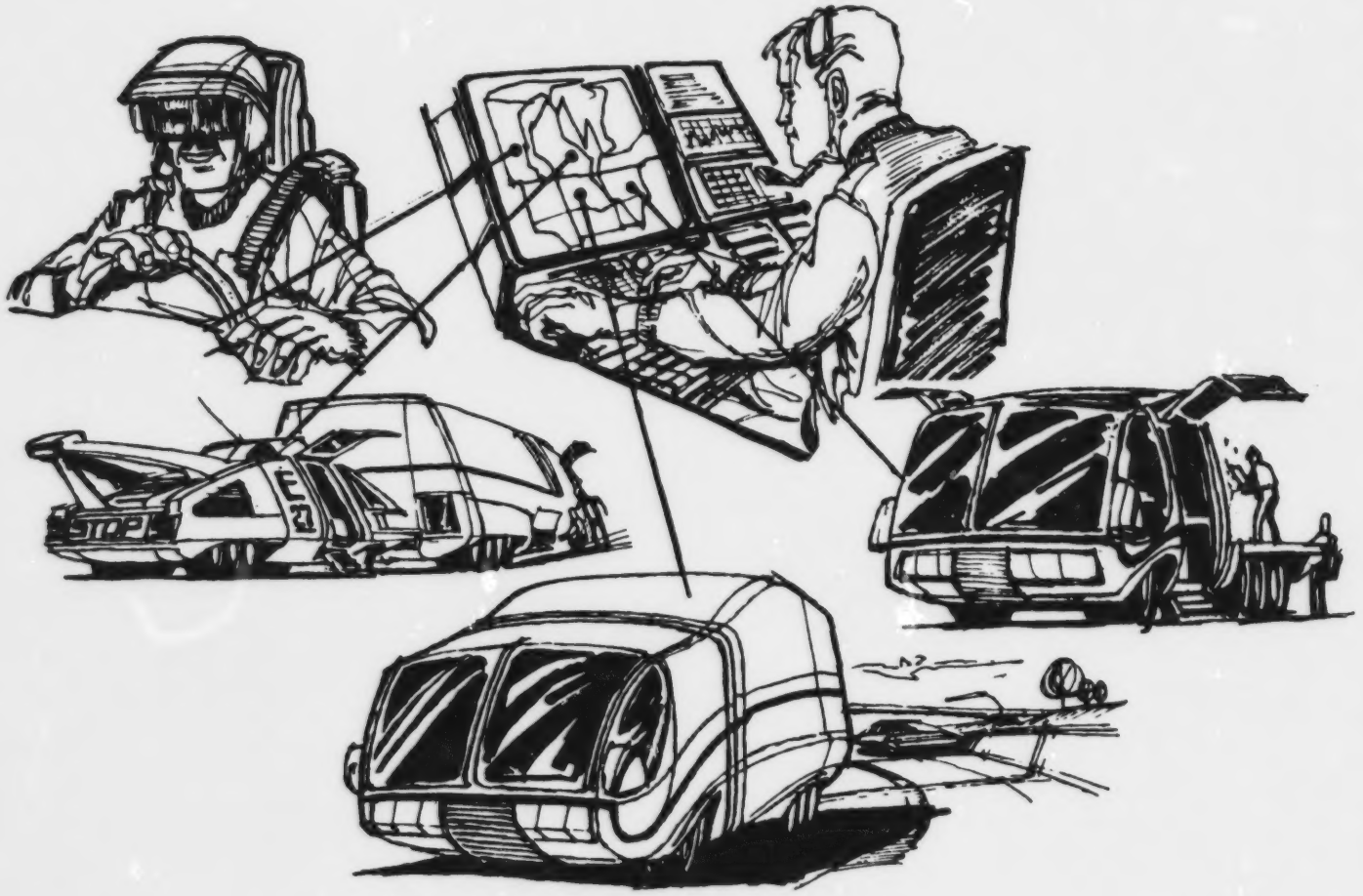
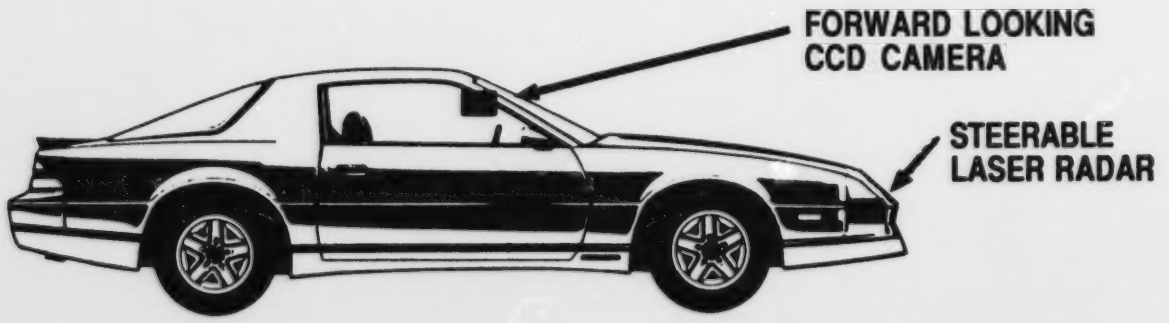
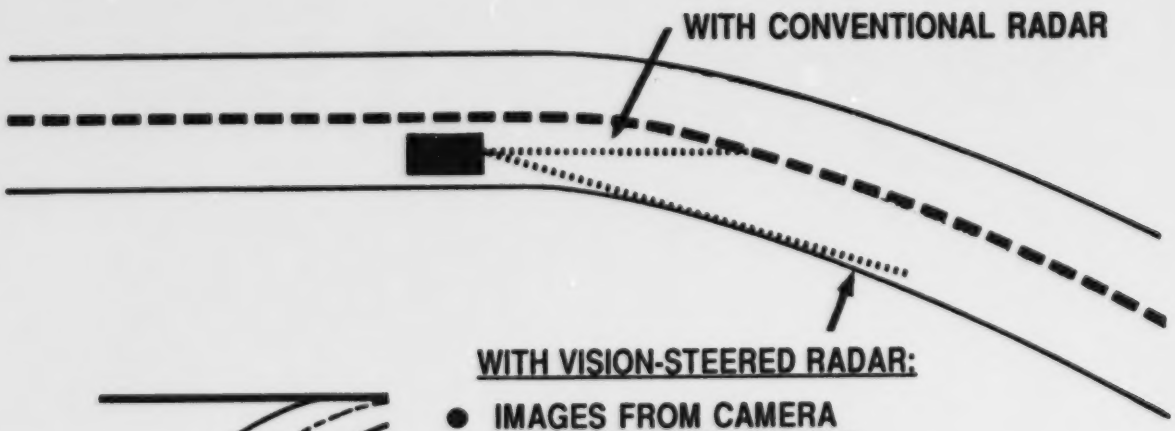
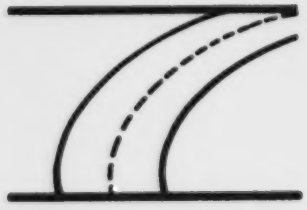


Figure 25

COLLISION WARNING
VISION-STEERED RADAR CONCEPT







WITH VISION-STEERED RADAR:

- IMAGES FROM CAMERA ARE PROCESSED TO FIND LANE BOUNDARIES AND CURVATURE
- THIS IS USED TO STEER LASER RADAR BEAM INTO CURVE AND INCREASE EFFECTIVE RANGE

Figure 26

WHAT'S GOING ON IN THE U.S.

ETAK Navigator
- Commercial Unit on the Market

UPS
- Navigator and Two-Way Communication
- 15 Vehicles in Los Angeles
- Several Thousand Emergency Vehicles in Detroit, October 1988

PATHFINDER
- Caltrans, FHwA, GM, 3 Years
- 25 Cars in the Santa Monica SMART Corridor

PATH
(Program on Advanced Technology for the Highway)
- Caltrans, FHwA, University of California-Berkeley
- Santa Barbara Bus - Electric Vehicle Propulsion and Guidance
- Automated Highway Test Track mid-90's

UMTRI-IVHS
(Univ. of Mich. Transportation Research Institute - Intelligent Vehicle/Highway System)
- GM, Ford, Chrysler, MVMA, Michigan DOT

Multi - State Consortium
- California, Michigan, Texas, Pennsylvania

Figure 27

WHAT'S GOING ON IN THE U.S. (cont.)

PROJECT 2020
- Highway Users Federation
- AASHTO

ASCE
- American Society of Civil Engineers

NRC-TRB
- National Research Council - Transportation Research Board

NAE
- National Academy of Engineering

AAA
- American Automobile Association

SAE
- Society of Automotive Engineers
- Committee to Standardize Navigation Map Data Format

Figure 28

WHAT'S NEEDED

- National Initiative
- Cooperative Effort
  - Federal, State, Local Governments
  - Automobile Industry
  - Computer, Electronics, Telemetering Industries
  - Universities
- Benefit/Cost Data
  - Demonstration Experiments of Different Aspects Under Different Conditions
- Research
  - Which Technology?
  - Reduce Cost
  - Traffic Theory
  - Artificial Intelligence
- International Cooperation

Figure 29

TECHNOLOGY AND URBAN PUBLIC TRANSPORTATION

R.M. Renfrew

Morrison Renfrew is Senior Vice-President of Engineering and Product Development of Urban Transit Development Corporation (UTDC) Inc. in Kingston, Ontario. Before joining UTDC, Mr. Renfrew was the Executive Director of the Canadian Institute of Guided Ground Transport at Queen's University.

1/ INTRODUCTION

In any discussion of transportation technology it is appropriate to restate the objectives of public transportation to remind ourselves why we are here. Our goals are to:

- Move people efficiently (efficiency = time and cost);
- Support the functionality of urban centres:
  - the town/city must be economically and socially viable;
- Contribute to environmental improvement:
  - reduction in pollution
  - effective land use
  - the automobile is consumptive of land and yields a low tax return on land committed to its use
  - energy management, especially long-term
  - urban aesthetics;
- Provide acceptable capital and operating costs (whether public or mixed finance).

The implementation and management of public transporation has a continuous influence on technology. In particular, the decision process by which project and technology are selected usually outweighs the intrinsic technical factors.

- Risk
  - Technical risk becomes political risk in a public environment. (Consider the difference between the Chunnel and the Scarborough Rapid Transit Line decision process)
- Liability
  - especially the U.S. legal context
- Competence
  - The decision makers are frequently subject to divisive conflicts of interest (political/public career issues versus freedom to manage risk) and many of them have no technical understanding
- Approval and Regulatory Authority Inputs - e.g., California P.U.C.

The difference between European project decision processes and those of North America has a lot to do with European technological superiority today.

2/ EXISTING TECHNOLOGY

The existing invested systems are primary because they have already fashioned the host cities irreversibly.

There are two general categories of existing technology:

- high capital cost/high efficiency/high service quality;
- low capital cost/uncontrollable efficiency/unpredictable service quality.

The Governing Factor is Infrastructure Cost

Infrastructure determines:

- accessibility (hence consumer attraction)
- capacity
- productivity

As we all know there are really only two basic systems:

- dedicated guideway
- road-based

Dedicated guideways can embrace a wide variety of systems:

- bus/rail/bicycle/jitney/HOV

The modal technology is secondary to the service level improvement realized by the dedicated guideway. A bicycle on a reserved bikeway is more effective than a streetcar in mixed traffic. We will refer to this as PRODUCTIVITY which is loosely defined as the

throughput per unit of investment (capital and operating cost).

The bicycle/bikeway example provides a slightly exaggerated example of a principle which has been long neglected to the detriment of effective public transportation.

Technology Should Be Assessed on an Investment Basis not on Emotional Enthusiasm

Streetcars are appallingly bad investments but they sure have a lot of emotional friends. The cost of capital of one streetcar would buy a new bus per year.

The biggest problem facing technology innovation in public transit is that there are no strings attached to the investment decision. If there were, we would make different decisions.

3/ EXISTING SYSTEMS

3.1/ Development Potential of Existing Systems

It is feasible to address development on several fronts. The subsets of productivity are:

- capacity
- efficiency
- operating cost reduction

The primary emphasis should be system effectiveness (inclusive of all elements).

a) Mixed Traffic Systems

Traffic management/priority options. These require only the political policy decision to enable implementation.

They include:

- signalling
- dedicated lanes (a quasi-dedicated guideway)

Operation options. These include:

- service frequency
- ownership alternatives to minimize capital and O&M cost

Both options involve labour issues with strong political vulnerability. In the UK significant benefits have been obtained by private operation of bus service under contract to public authorities

Summary

Mixed traffic system improvements depend largely on political and regulatory will. The productivity gains can be significant. The investment criteria are largely irrelevant because the road is free to the operator (although not to the user).

b) Dedicated Guideway Systems

The priority here is productivity improvement from existing infrastructure. A subway tunnel represents an investment value of $80-100 million per system kilometre. The typical design throughput is 40 000 passengers/hour/direction.

To upgrade a subway to 50 000 pphpd would involve:

- automation - $2 million/km
- station improvements - say $10 million/station (it will be very site-specific and dependent on special factors such as entrance and exit locations)

The marginal economics of upgrading are usually positive if the equipment is capable of meeting the marginal performance improvement. (This will not always be true.)

Commuter rail systems probably represent the best upgrading opportunity in North America. They are usually limited in headway and capacity by signalling, traction, train size, and terminal station capacity.

Headway upgrades through signalling can be achieved at $100K/system kilometre.

New creep-controlled locomotives can provide significantly higher tractive effort to haul heavier trains at higher acceleration.

Electrification is a higher capital cost option but it brings virtual subway system performance to commuter rail at a cost of $1-2 million/kilometre.

Any of these options is a consistently better investment than highway capacity.

The marginal economics of commuter rail improvement are very attractive:

- reduction in headway from 20 minutes to 5 minutes;
- increase in capacity (several fold);
- most railway track is under-utilized in urban areas and has available capacity;
- simple downtown feeders can be converted to regional networks.

The key factor is that the rights-of-way exist and require no political decision other than the regulatory authorization.

The ancillary developments, such as park-and-ride lots, are essential but come at a moderate cost if they are in the outer suburban areas where the passenger interception is most effective.

Several cities have gone beyond the traditional concept of commuter rail. London has the Thames Link which runs through the heart of the city. This was achieved by rearranging schedules and providing dual-voltage equipment.

Paris has the RER which is a higher density service than the Metro.

Tokyo operates commuter and subway trains in a mixed service through the same tunnels.

The cost of upgrades of existing railway track are modest compared to new tunnels or elevated structures. Connecting linkages can be less expensive than major transfer stations. The sevice quality improvement can significantly improve the attractiveness versus the automobile.

Busways and guided bus systems offer a retrofit concept as a means of productivity improvement. The economics are questionable on an investment basis. Where a private, dedicated busway exists, it is generally cheaper to upgrade to rail than a guided busway conversion and the productivity through automation is higher.

As long as the driver remains in the system, the guided bus option is weak.

Light rail is not an easy upgrade option in most cases. The development potential is limited by crossings and mixed traffic zones. Because of these the system will always be headway constrained.

A fully segregated LRT system is the same as a subway for all practical purposes – and usually costs about the same.

c) Computer Technologies

A wide range of developments have demonstrated effective benefit in reducing operating cost and improving reliability.

AC traction is now widely accepted. The cost has steadily reduced over the past five years and is now virtually competitive with DC chopper. The reliability is excellent and growing steadily.

Maintenance diagnostic systems have proven effective in reducing capital cost due to reduction in fleet sizes. The Vancouver SkyTrain utilizes the entire fleet during peak hours. The Central Line replacement fleet in London will be reduced by 10% due to the forecast benefit from diagnostic systems.

These systems also reduce the dependence on experienced troubleshooting labour as shown by the contrast between the Scarborough Rapid Transit Line and the subway in Toronto.

Sealed equipment packaging greatly increases equipment reliability and life.

Automation by computer-based signalling systems reduces staff costs and improves operating reliability. Both Vancouver and Lille have labour costs of about 55% compared to industry averages of 70-75% of operating cost.

The data obtained from the management systems is a significant benefit in planning and operating systems.

Vehicle structures now incorporate composites which yield reduced weight and increased corrosion resistance.

Internal combustion enginelife, reliability, and fuel economy have steadily increased due to materials and design improvements. Diagnostic systems are now common. Alternate fuels offer reduced emission levels.

Summary

There is a lot of potential for improvement of existing systems. If some institutional factors were revised, the rate of introduction of improvements would be greater:

- Prepare the way by planning, training personnel, and understanding the economic benefit objectives to ensure that they are in fact achieved.

- Recognize that the higher the technology, the more system-oriented (as a rule) the decision becomes.

- Recognize that the greatest gains are at the system level which implies a more fundamental analysis of the options and return-on-investment.

- Recognize that the introduction of system improvements is generally hindered by the inability of operating authorities to plan on a sufficient time horizon and by a lack of objective investment analysis.

Failures in new technology introduction are largely the result of the lack of due process in North America. Prototyping, implying long-term commitment, is almost non-existent leading to much higher risk in the introduction of technology. By contrast Europe and Japan practise extensive prototyping and have, as a consequence, become the leaders in technology growth and implementation.

4/ NEW SYSTEMS

4.1/ The First Law – New Systems Are Not a Panacea

New systems are largely an aggregation of new and existing component technology. The significant difference lies in the system application objectives.

New systems can be retrofit options for existing infrastructure, provided that the logistics of transition are feasible; e.g., it is not feasible to shut down a major subway for one to two years, therefore any transition must be a parallel operation.

New systems depend heavily on planning provisions:

- Lille VAL was ten years in planning
- SkyTrain utilized existing right-of-way

Political and planning processes have almost killed new system development, even in potentially economically viable applications. No U.S. consultant will accept professional liability exposure on a new technology. There are no authorities in Canada or U.S. who can certify technology. Europe and Japan have legally recognized authority and process. No European manufacturer has declared bankruptcy as a consequence of a European supply contract versus U.S. where everybody has gone bankrupt.

New systems should be targetted at market needs. These are overwhelming in large (greater than 1 million population) and medium-sized (greater than 250K population) cities. The problems of smaller cities and special interest group needs (E&H) can be solved by existing options provided the political and planning will exists.

In practice, new system technologies are targetted at perceived marketing priorities. This is due to the dependence on public development funding which is generally obtained by lobbying a political champion whose knowledge of transit is marginal, or highly biased by emotional leanings.

The lure of industrial benefit, through creation of a gigantic industry, is irresistible to the uninitiated. As a result even the prosaic and methodical Japanese have more new transit technology than any national market analysis could possibly justify – much of it of very dubious technical merit.

New system technology can be categorized by a few technical characteristics:

- propulsion and braking
- suspension
- switching
- control

The system characteristics are determined by these subsystem choices. The system can be high or low capacity, small or large vehicles, short or long headway, regardless of the subsystem choices. (Of course the choices have significant, specific, design impacts which are strong influences on the system characteristics.)

However the operational requirements (reflecting user and operator priorities) are constrained by some very basic considerations:

- emergency evacuation
- accessibility provisions
- system dependability
- station operations
- maintenance costs
- safety
- environmental impact

There are conflicts between technology and requirements which frequently rule out relatively well developed subsystem technology. For example, monorails have difficulty meeting the combined safety, emergency evacuation, and environmental impact criteria.

Very short headway PRT (Personal Rapid Transit) concepts require high emergency braking rates. These conflict with the safety of standing passengers. Seated-only arrangements which allow high performance conflict with accessibility.

Small vehicles result in lower overall system dependability because of the mathematics of reliability. If the small vehicles must operate in trains to achieve system operational reliability, it is pointless to use small vehicles in the first place.

Suspended vehicle systems have both evacuation and switching problems. The extra height of the guideway results in a more obtrusive appearance.

The proponents of new system technology most frequently ignore the infrastructure issues.

- Tunnel sizes are determined by passengers, not technology.
- Elevated structures require columns. The longer the span the larger, the columns and foundation. The dead weight of the structure is more significant than the light weight of the vehicle in determining size and cost.
- Alignments for structures within existing streets are highly constrained. Station sites are often problematic due to both access and aesthetics.
- Underground utilities present costly problems which limit the siting of columns.
- Nowhere do residents wish to have elevated structures adjacent to their homes or apartments. The concept of PRT systems serving residential areas is virtually impractical on both economic and environmental grounds.

4.3/ The Identifiable Need for New Systems

There are critical needs for systems offering significant improvements in:

- capital cost
- productivity
- service dependability

to serve large and medium-sized cities.

The cost of conventional subways has become politically sensitive and out of proportion to the tax base of many governments. There is a lot of competition for the public dollar.

The medium-sized cities are in the worst no-man's land of all. They do not typically have high density corridor demands for transit, yet they do have high density automobile congestion. Due to the autos, they cannot operate an attractive bus system, and since parking is usually reasonable in price (at least compared to large cities) there is a strong incentive to drive.

Some North American medium cities may have options to adopt traffic management schemes, but many do not. They, and others like them in Europe, are simply strangling on the affluence of the population.

The response (in North America) to both situations is urban sprawl. Unfortunately this is not a long-term solution since other social costs will rise rapidly and the

cost of public services maintenance will become unacceptable. We see that the renewal costs of roads, sewers, and water systems have now reached crisis levels.

4.4/ The Synthesis of New Systems

The solution for the large city is straightforward. The majority of the systems will be underground, except in the suburbs. Small cross-section tunnels and simple, short stations represent the greatest opporunity to reduce capital cost. Our studies show a potential reduction of 25-30% in total system cost by exploiting smaller size and length trains operating at 80-100 second headways. Such headways require full automation to maintain schedule reliability and safety.

UTDC is currently developing the technology for such a system. Based on the historical operating costs in Vancouver we know that major operating cost savings will be achieved. Parametric cost analysis based on actual construction costs of tunnels has indicated capital cost reductions within the target range.

Japan has two projects of this type now under construction in Osaka and Tokyo. The published Japanese cost analyses are consistent with UTDC forecasts. UTDC data is not accurate enough to distinguish the marginal differences between variations of the mini-metro. The Japanese however have decided to use the linear motor in preference to the conventional rotary drive because there was an additional net saving of 6% on the life-cycle costs. We are obviously pleased by their conclusions.

Even though Japanese and Canadian entrants in the new metro technology utilize steel-wheel on rail there is active competition from maglev and rubber-tire technology.

Japanese and German maglev systems are being implemented in Las Vegas over the next several years. These will be essentially demonstration systems in the non-transit environment of Las Vegas.

The technologies a.e fundamentally different. The M-Bahn (AEG) is a suspension system which uses uncontrolled permanent magnets to levitate the vehicle. The air gap between the magnet and the rail is maintained by rollers which are connected to the car by levers. The roller-lever system reacts to changes in the passenger load so as to maintain a constant air gap.

The propulsion is achieved by a "long-stator" synchronous motor. Long-stator means the motor is a continuous winding built in to the guideway. It utilizes the suspension magnets as reluctance motor poles to propel the vehicle. The speed is controlled by the frequency of the current in the long-stator primary winding. This is a synchronous type of control.

Although this technology has the potential for very quiet operation, it has several operational drawbacks:

- The air-gap maintaining rollers are limited to low speeds due to heat buildup.
- The long-stator propulsion system is inefficient due to the very low power factor.
- The synchronous control concept is quite inflexible and transfers the reliability from the vehicle to the track. There is no redundancy possible in the track, except at considerable cost and complexity.
- The switching requires a "flexible" guideway section to be moved to provide a continuous track. Maglev cannot cross a significant gap in the levitiation rails.

The Japanese HSST maglev is a licensed descendent of the Krauss-Maffei Transurban development of the early 70s. It incorporates active magnet control on the vehicle (passive guideway) and uses a conventional control system. It has been demonstrated at speeds up to 250 km/h. It is currently offered in three speed ranges – 100, 200, and 300 km/h.

While it is a considerable improvement over the primitive system offered in 1975, and the power electronics technology is simplified and has improved reliability, the basic levitation power of 1 kW/tonne is still a significant disadvantage. The payload of a maglev vehicle is a strict function of the magnet size and power, and is automatically less than the payload of a wheeled vehicle. Since the aerodynamic losses of maglev

vehicles are the same as those of wheeled vehicles, the propulsion requirements are identical. (The rolling friction of a steel-wheel is a very small proportion of the required traction effort.)

It is difficult to see how maglev can become a serious contender in the urban transit market when a systematic selection process is applied to the technology. However the emotional decision factor in the political constituency will respond to the claims of the suppliers until the performance is proven by service experience.

The real competitors to steel-wheel-on-rail are the rubber-tired systems. These have established a solid track record in airports and urban transit applications. They are claimed to be quieter and to achieve higher performance.

The rolling resistance and resultant heat buildup of the rubber-tire limits such systems to the lower speed applications, of which airports are typical. Monorails and conventional rubber-tired systems are both limited by the problem of heat buildup. Monorails have a marginally more severe problem due to the limits on tire size imposed by the vehicle floor height.

Rubber-tired systems are excluded from full capability transit applications because of their maximum sustained speed of 60-70 km/h. The new RATP (Paris) system, METRO 2000, is a steel-wheeled system using single-axle suspension with rotary AC traction drive.
In UTDC's program to achieve capital cost reductions we have found that electronics technology can reduce cost to a considerable extent.

New vehicles will have an integrated on-board control system which eliminates many of the "black boxes" in the current system controls. By using digital data we have eliminated most of the wiring.

Because propulsion technology, based on the GTO, is now highly reliable we have halved the redundancy with significant savings as a result.

The overall effect of these developments will be to bring the automated vehicle technology down to the price of today's conventional vehicle on a unit capacity basis.

System capacity ranges of 13 000 to 60 000 pphpd are achieved by variable length trains of two to nine cars. In effect we have created a technology which covers the entire rapid transit spectrum using a common car design.

The vehicles are designed to accept pantograph or third rail power collection. The propulsion can be either rotary or linear to suit the application. The basic truck technology can be non-steered, self-steered, or forced-steered to meet the track geometry requirement.

This is the first system technology to specifically address the unique aspects of individual applications based on a standard family of technologies which can be configured in subway, commuter, or people mover systems. It is currently being considered for Honolulu (8 000 pphpd) and Bangkok (50 000 pphpd).

4.5/ Systems for Medium-Sized Cities

Infrastructure cost is the barrier to service and productivity. At this time there are no good solutions to the needs of the medium-sized city, and there are no magic solutions on the horizon.

Light rail is considered by many to be the ideal solution. However all of the productivity weaknesses and service limitations of a manually operated system apply to light rail. Automation solves these problems but only at generally unacceptable capital costs. PRT does not have the answer. Recent light-rail project costs have been distinctly discouraging in terms of value for money.

The needs of the medium-sized city is the challenge of the 90s. Are there any feasible options? If there is a positive answer, the commercial rewards will be significant.

In a constrained funding situation (a universal constraint outside France and the FRG) the infrastructure cost is the issue which must be addressed to open the market.

At-grade systems are insensitive to technology. Elevated or underground systems are marginally susceptible to incremental cost reductions. There are only two avenues of approach:
- significantly cheaper tunnels

- simpler, cheaper elevated guideways.

The environmental, political, and urban design factors seem to be strongly in favour of subway alternatives. There are two dominant factors open to improvement:

- the size of the tunnel
- the contract conditions under which construction is awarded.

The size of the tunnel involves minimum vehicle height, ventilation, and provisions for emergency evacuation. The minimum tunnel to achieve all of these is about ten feet. If such tunnels can be constructed on the same general basis as a watermain, there may be a significant cost reduction.

The technology to achieve such low-profile vehicles is available. The suspension and guidance of the flanged steel-wheel is again the winner due to wheel size (hence floor height and overall vehicle heights), load capacity, and speed. The propulsion options include rotary or linear (on-vehicle or in-track). Further analysis and prototype work is required before definitive options can be confirmed, but results to date are positive.

The capital costs of the prototypical LCTS vehicle (developed by UTDC and Alcan) are comparable to a bus. The operating and maintenance cost projections are well below the bus.

5/ SUMMARY AND CONCLUSIONS

The urban transit industry has passed through the technological upheaval of the 70s and is now proceeding into the 90s on a pragmatic basis.

Evolutionary technology is dominant, as is the case in intercity rail and air transport. A revolutionary new entrant is unlikely because infrastructure costs and operational considerations are now more precisely defined and applied, and they indicate no radical performance requirements.

The pressures on the transit service industry are little different than any other business. It is a labour-intensive operation with high capital costs. The objective must be to minimize the total life-cycle cost specific to the application. The technology to achieve this has been proven in the 80s and will continue to improve in the 90s.

A key factor in realizing improved transit cost performance objectives will be the procurement process for new projects and equipment. The traditional approach frankly does not work well. The organizational structure of North American transit operations is not geared to deal with technological innovation. The best way to encourage change would be to require investment accountability rather than the Reagan administration approach of decimated budgets. Such an approach would embrace all aspects of transit technology and implementation, including project financing and management which offer considerable scope for cost reduction through, for example, turnkey systems responsibility.

The technology is equal to the challenge.

MODE:	RAPID RAIL (Underground)	LIGHT RAIL (LRT) (Surface)	ADVANCED LIGHT RAIL (ALRT) (Elevated)	BUSES (On Street)	BUSWAY (Line Haul)
CAPACITY (10^3 passengers/hr/ direction)	40	10-15	30	3	8
FREQUENCY OF SERVICE (rush hour - minimum)	2	2	1	1	1.5
TYPICAL AVERAGE SPEED (km/hr)	40	30	50	16	40
CAPITAL COST (million $ per system kilometer)	80-100	20	40	2.5	10-20
CAPITAL PRODUCTIVITY ($ per/km/pphpd)	2500	1333	1333	1000	2500

FIGURE 1: CAPITAL COST VERSUS PRODUCTIVITY

	SUBWAYS	LIGHT RAIL	BUSES
CAPACITY (Passengers/hr/direction)	40,000	10,000	3,000
FEQUENCY OF SERVICE (Rush Hour)	2 minutes	2 minutes	1 minute
TYPICAL SPEED (mph)	25	20-25	10
LENGTH OF STATION PLATFORM	450 ft.	170 ft.	--
TRAIN	6 cars	2 cars	1 bus
TYPICAL VEHICLE OPERATING COST/HR (Inclusive of overheads)		$72	$34
PROBABLE AVERAGE VEHICLE REVENUE/HR		$27	$9.50
APTA OPERATING RATIO (1980)	50%	29%	39%

FIGURE 2: PRODUCTIVITY COMPARISON

	100 PASSENGER (CRUSH-LOADED) VEHICLES			
	ALRT (LIM Traction)	RUBBER-TYRED AUTOMATED SYSTEM (France) (DC Rotary Traction)	STEEL-WHEELED AUTOMATED SYSTEM (Japan) (AC Rotary Traction)	MAGLEV (LIM Traction)
TARE WEIGHT - kg	14,500	19,000	20,000	16,000
SUSPENSION Energy loss at 80 kph-KW	7.8	40.0	12.8	23
Approximate aerodynamic losses at 80 kph-KW	32	32	32	32

FIGURE 3: ENERGY EFFICIENCY OF INNOVATIVE TECHNOLOGIES

TECHNOLOGY AND INTERCITY PUBLIC TRANSPORTATION

Greg Wood

Greg Wood is President of N.D. Lea International, a company that conducts research in rail and other guideway technologies, and former Executive Director of the Canadian Institute of Guided Ground Transport.

I'd like to focus our attention today on the inter-city component of transport. And because my background over the last three years has been very heavily focused on the railway mode, that's the primary focus of my talk today.

Before we head into the technology aspects, the theme that I would like to push this morning is, what is affordable and what can we buy with what we spend? And is it a good deal? A lot of the work that we've done at the institute over the last few years has been focused on getting more from what we already have, rather than necessarily building something that is totally new and different. I think this fits also into the theme that we've heard from other speakers that we're not looking at revolution, we're looking at evolution. I think the theme for transport is resiliency, cost effectiveness, and evolution.

For sake of comparison and discussion, this slide shows the distribution of trip-length by mode [slide #1]. You can see the market that we're fighting against. We can see that the automotive mode in the all-trip category is carrying almost 90% of all the new city trips. And the rest of us are scrambling for the remainder. The automotive mode for all trips is carrying 89% of the traffic, the air mode carrying 5.1%, the bus mode 2.9%, and the rest are carrying 2.5%.

What we're trying to provide in the other modes is an alternative. We're trying to say, all the good things that are happening in the automotive mode may well be attractive, may well help, in reducing congestion. But one of the other options is to provide a viable alternative. Some other technology that can provide a level of service and a quality of service and a cost of service which is comparable and which is attractive. And that's the challenge that we're facing.

I'd like to speak for a few minutes on this whole issue of high-speed rail. You've all heard the news that has been coming out from the provincial government, from VIA, and from various private sector companies and consortia, including the UTDC, Lavelin, and Bombardier, about the prospects for high-speed rail down through the corridor between Montreal and Toronto.

At the institute, we've been working for many years through Morrison's period and also through my period in the high-speed area with many clients. We're working with Florida, we're working with the states of Nevada and California, and we're currently working with the Koreans on their line between Pusan and Seoul.

There is a lot of activity and a lot of interest around the world in high-speed rail. Why is that? What is it that it offers that's attractive and where does it sit in the spectrum of service that can be offered? The sense is that we have a technology here whose time may have come, particularly for the medium distance trips. These are the trips up to 500 km or so. And it looks as if this technology can be cost-effective, depending on what the cost of capital is and what the cost of infra-structure is that we're having to put up to build it.

The next slide [#11] basically shows where we stand in that competitive range. At the top of the slide you can see some of the Japanese examples. It shows what the catchment area is in terms of size of market that they're serving; it shows what the market share was before they started; and how far they're travelling. And at the end of the slide, roughly what their commercial performance is. Now as you can see, at the top of the slide, it shows that some of the Japanese systems are paying for themselves, and they are paying a profit both on operating and capital cost. Some of the Japanese systems are not paying their capital costs, they're only covering their operating costs. And they're doing that in

markets that are around the same size as the market that we're seeing between Toronto, Ottawa, and Montreal. That is, we have a market which is comparable to what some of the Japanese systems are serving now, but they are not covering their total capital cost, nor are we expecting to cover the capital cost in that market either.

This comes down to a question of, how do we finance it then? Is there money in the system, either at the provincial level or the federal level, to be able to supplement the money that may come from the private sector to put this together? And I think some of the work that we have been doing recently has shown that the benefits that can be achieved by the provincial level especially make it attractive to put some of the funding up. I think that's where we stand right now in the discussion. We're looking at the cost-effectiveness and we're looking at what the provinces can afford to contribute to this process of supplying front-end funding for the infrastructure to put a high-speed system in place. My feeling is personally that in the next ten years, we're going to see a system in place between Toronto, Montreal, and Ottawa.

What kind of system are we looking at? Here is a comparison of the different speeds that fall into the general category of high-speed [slides #12, 13, 14, 15]. Currently, we're operating with LRC systems and a current service called the high-speed train in Britain. What we're seeing there is basically speeds that run between 155 and 200 km/h. This is the lower end of what we would normally consider to be high-speed.

The next step up the system is moving over 200 km/h. What we're seeing there is the kind of service that's being proposed for Florida, where we're looking at the range of 225 to 240 km/h.

The third category moves up into the 300 km range. And that's what we're looking at in the current service that's operating in France with the TGV. Here is an example of what the TGV system looks like. I think you've seen examples of it. I've got two other examples of the German system and the Japanese system. Here is the German system. This is the electro-magnetic system and you can see it's being suspended on a guide rail and the magnet pulls the equipment up off the rail and suspends it over the rail.

The Japanese railway system is the reverse in that it's a repulsive system. It's pushing the equipment up off the railing and holding it there. These are the two basic current technologies in the maglev technology range [slide # 18]. And these are the ones that are working in the 400 km/h range. Now we don't see these as being very attractive and very viable, probably for the next 15 years. What we're looking at for the Toronto-Montreal-Ottawa system is something more in the 300 to 350 km/h range. This summarizes the three maglev systems that are currently being examined.

I'd like to switch over to some of the other technology areas that we're working in. We've been working for some years now with the motive power area. There are a lot of examples of improvements that can be achieved in improving the motive power of mainland railways. These range from improved energy systems, improved tractive power, various improvements in enhancement of performance, getting more axles with more power on the track, and improved retrofits.

Now, the work that we've been doing with the industry and the government on this is to try to find out which of these technologies is cost-effective and which ones will pay for themselves in the longer term. I'm sorry you can't see that very well but the range across the bottom is the level of tractive ratio that we can get onto the tracks and along the vertical axis is the net present value of the savings that can be achieved [slide #10]. And the different bars represent the savings that are achieved from different elements of improvement, including the maintenance, the fuel, the other aspects. And it shows the improvement especially that comes from the maintenance side. Maintenance in the locomotive area is predominant and the improvements that can be achieved in cost-effective operation mainly come from the life-cycle costing in the maintenance area.

We compared the benefits of retrofitting existing equipment versus the benefits that could be achieved from improving new equipment and how much we would have to pay for those improvements. And what this

shows is again with the improvement in the performance ratio, the kind of achievement in net present values savings that can be achieved through retrofitting existing equipment and improvement in new equipment. What this shows is that the benefits in new equipment, in fact, far exceed those achievements that we can obtain in energy efficiency and in improvement in operations for retrofits.

The major exception to this is the improvement in energy efficiency that can be achieved from some of the existing technologies. The next set of slides I'd like to show you is what has been achieved through some work we've been doing with the Ministry of Transportation in the GO Transit corridor between Oakville and Toronto. Some years ago we had a gentleman join us from the Southern Australian Institute of Technology in Australia. One of the areas that they had been working on in Australia was to take commuter rail and to look at how they can improve both the schedule adherence and also the energy use of a commuter rail service. The argument behind this was that the drivers of a train in a commuter rail service often do not achieve very tight schedule adherence and they use more power for acceleration and braking than they need to. And since we know the size of the consist, we know the distance between the stations, and we know the schedule that should be achieved, it should be possible to develop a driver advisory system which will enable us to drive the train more effectively and more efficiently and thereby achieve some energy savings.

The concept behind it is that we have an acceleration curve, we then have a coast curve, and then we have a braking period, which allows the train to come to a specific stop at a specific point in time. The driver advice system is essentially a light system, which sits in the cab and gives the driver instructions as to when to accelerate, when to coast, and when to brake. We installed a number of these systems in some of the cabs in the GO system and ran the service over a number of weeks to see what kind of benefits we could achieve. Here is an example of the GO trains that it was installed in. And here is an example of the stations along the line that we served during this demonstration.

The concept as shown here, if you can look at the two curves, the top one shows essentially the driver-controlled system and it shows how the train accelerates, then how it coasts and how it brakes. With the driver advice system, what we're basically doing is trying to see how we can chop off the point, the excess energy point on that curve. You can see the difference between the operation of the train under the driver advice system, compared to what it was like under the driver-control system.

The aspect that is not measured too often in this kind of energy study is the ability of a service like this to improve the quality of schedule adherence. In the Southern Australian example, which is shown here, you can see the scatter of the arrival times of the trains coming into a station. You can see they're scattered quite widely around the expected arrival time. Once, having put the system in place, you can see a dramatic improvement in the way in which the schedules are adhered to. The standard deviation is reduced substantially, and we're getting a much tighter distribution around the arrival time. This is application both in the commuter system operation, as well as in the subway service operation, in that as we get more and more congestion, we're going to be trying to reduce the scatter around the arrival time so that we can put more traffic through on the same track in the same time period.

In the operational assessment that we did for GO Transit, what we showed was (there are two measures being examined here): one is the actual fuel used in litres of fuel, and the other is the actual energy being put into the system through the tractive effort. If we're looking at the fuel cost and the fuel consumption, this includes the power that is used to power the heating system on the vehicle as well, the savings were about 12%. If we're looking at the tractive energy put into the system to move the train, the savings were up around the 20% range.

So, we can see that with just enhancements of operations, just enhancements of the way in which we control the system, we can come up with substantial improvements in the quality of energy used and the cost of operating that system.

Now with the technology of mainline freight service, and I guess in some ways they apply also to passenger trains, one of the areas that we've been working in is the retrofit of existing tracks with concrete ties. And one of the justifications for this is, as you can see here, this is a bridge which is on fire and what we're burning are wooden ties on the bridge. Now, concrete ties provide a lot of benefits. One is the stability of the track, the structure, the strength, and its maintenance cost over time. The other thing it provides is a guarantee that you're not going to have bridges out of service because they've been cut or they've been set on fire by either a grass fire or a brush fire.

Here is a slide which shows a comparison of a concrete tie structure meeting up with a wooden tie structure. Now, one of the issues with concrete ties is resiliency. It's the ability of the tie to accept the loads that are placed on it in dynamic loading. Dynamic loading is a key issue when you get into concrete ties because we're looking at a very rigid structure and essentially it's the same as hitting that structure with a series of hammer blows. One of the causes of those hammer blows is the flats that occur on some of the wheels that are caused by braking and as the flat comes around and hits the rail it sends a tremendous load down into the tie. In some cases, this can be measured to be up to 400% of the static load. The effect of these dynamic loads is that we get corrugation on the rail head, and we get severe cracking occurring in the concrete ties under the pad and under the contact point with the rail. You can see where the concrete tie in cross section starts to crack underneath the connection with the rail and where the tie pad sits on top of the tie.

This overhead shows two different kinds of tie pads [slide #23]. On the top of the slide, you see a traditional tie pad, which is just a neoprene pad without any special attenuation design attached to it or design into it. And you can see on the graphs adjacent to it, the kind of variation of strain load that you get in the tie itself. There is a tremendous spikiness and peakiness in the load that's transmitted through the tie pad into the tie and this peakiness and spikiness is what causes the cracking to initiate and to start under fatigue. In the bottom part of the slide it shows what happens when you change the tie pad and build more resiliency into the tie pad so that the transmission of load through to the tie is essentially taken up within the movement and resiliency of the tie pad itself. And you can see how it smooths out tremendously the amount of strain that's transmitted through into the tie.

Some of the work that we're working on is aimed at trying to improve this transmission of strain through to the tie and thereby extend the life of the concrete ties and remove this problem with cracking that's been occurring.

Just, finally, two or three slides to show some work that's going on in the rail itself [slides #24 & 25]. Rail is one of the biggest cost items that the railways have to deal with. Replacement of rail is one of their largest budget items. And one of the problems, as I mentioned before, is that corrugations occur very quickly in high-speed service as well as mainline service on top of the rail head. The way in which they're removed is by grinding. We have huge grinding machines that go along the rail and take off the corrugations. One of the problems with that is that as you grind the rail head away, you're wearing it down. It becomes thinner and thinner and therefore, at some point, you reach a stage where it's not safe to operate on that rail anymore. And you may be reaching a stage where you can have broken rails and therefore derailments and unsafe operating conditions.

One of the things that we're working on is doing a finite element analysis on the rail head to show how far we can take that grinding process before we start to lose strength sufficient to enable us to stop operation and condemn the rail. We place loads on top of the rail in the finite element analysis at different spots to try to show what the impacts are of different kinds of loading regimes on different levels and different sizes of rail under different kinds of grinding conditions.

Here is an example of the stress analysis that has been done, which shows a typical full-size rail with a fairly typical load sitting right on the top dead centre of the rail and shows the stress concentration underneath the contact points on the gauge face and under the centre of the rail head.

I'm sorry there is one slide missing. The second slide was to show what happens when we have this configuration, which is the worn head configuration, and which shows where the strain would come underneath the worn head configuration. The aim of this analysis is to show us how far down in the grinding process we can go before we start to reach a point of diminishing returns and it's not valuable anymore to take it down any further.

In summary, what can we learn from the experiences that we've had? I think over the years what we learned from the research experience at the institute has been that we can take existing technology, we can analyze the technology, and we can come up with some fairly effective ways of applying the technology. The technology itself is not important. There are many, many technologies available in all the aspects of inter-city transport, both for heavy freight as well as inter-city passenger transport that we can examine. But the critical aspect for us is at what point does it become effective to apply that technology and what kind of benefits can we achieve from it? In the high-speed area, we're looking for combined investment from both the public sector and the private sector. From the mainline railways, we're looking at improving the quality of their technology, improving their effectiveness, improving their productivity in the face of increased competition from all sources, mainly the trucks in Canada, but also increasingly from the States. And how does that system work in a way which keeps our country more competitive? I think the kind of lessons that we've learned is that there is technology there that can do that and it's a matter of how to apply that technology more effectively and to get the main benefit out of it, without a huge increase in cost. And with that I'd like to close.

Trip Length by Type of Transportation, 1988

Length of Trip	Total	Auto	Air	Bus	Other/not stated
	thousand of person-trips	percentage of total			
All trips	133,273(1)	89.4	5.1	2.9	2.5
Short trips under 320 km de 320 km	99,771	94.3	0.4	2.6	2.7
Mid-length trips 320 - 799 km	22,813	80.8	11.6	4.1	3.5
Long trips 800 - 3,199 km	8,948	56.3	37.1	2.9	3.6
Transcontinental trips over 3200 km	1,220	12.0	68.7	0.6	0.7

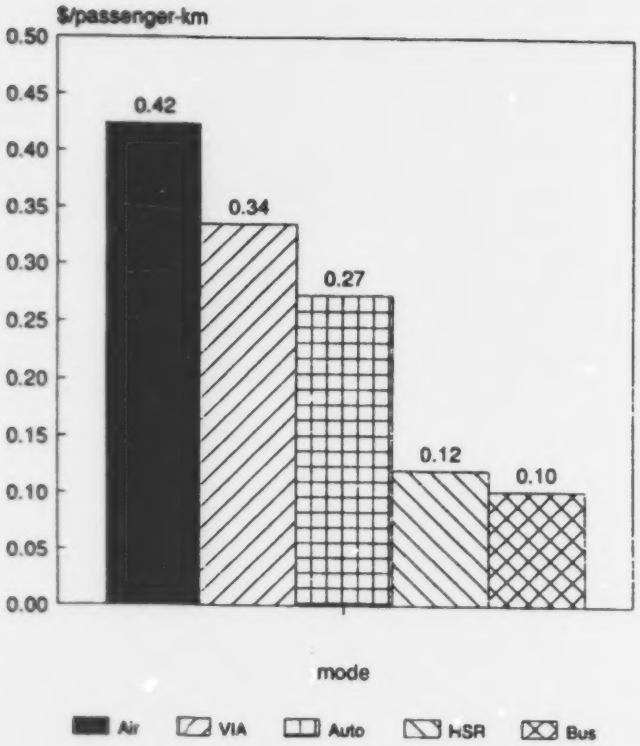
(1) All trips include 2,520,000 person-trips for which distance is not stated.

Source: Canadian Travel Survey.

Source: D.Rankin, B.Chadwick, "Transportation Used By Canadian Travellers", Canadian Economic Observer, August 1988

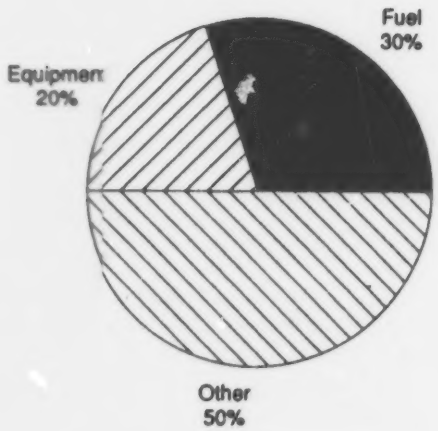
Slide 1

Cost of Transportation
By Mode



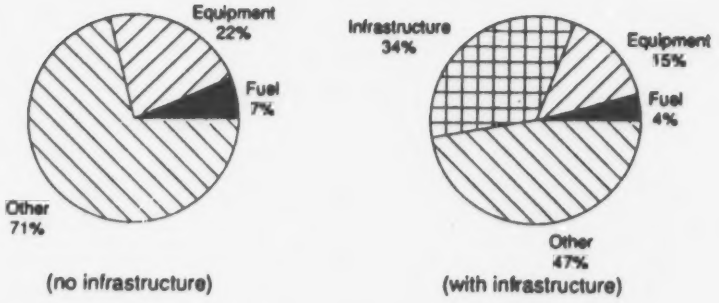
Slide 2

Air Transportation
Operating Cost Breakdown



Slide 3

High Speed Rail
Operating Cost Breakdown



Slide 4

Air Transportation Developments

- Propulsion
  - fuel efficient turboprop and turbofan engines
  - ultra-high-bypass ratio propfan engines
  - counter rotating propfans
  - new propellor design

- Airframe
  - weight reduction
  - new, lighter, stronger aluminum alloys
  - thermoset composites
  - thermoplastic composites
  - improved wing aerodynamics (laminar flow)
  - improved fuselage aerodynamics (rivlets)

- Avionics
  - sophisticated flight management systems (FMS)
  - improved air traffic control (ATC) systems
  - microwave landing systems (MLS)
  - global positioning systems (GPS)
  - onboard collision aviodance

Slide 5

Air Transportation Safety

Human error is a contributing factor in approximately 65% of all accidents involving commercial jets and 85% of general aviation accidents (in the U.S.A.).

Technology considerations:

Advanced automated systems, both in the cockpit and at air traffic control (ATC) stations, can be used to assist humans in the effective management and performance of their tasks.

- potential for 50% reduction in human error accidents
- potential for up to 20% increase in airspace capacity
- reduced workload for aircrew and air traffic control staff

Financial considerations:

Onboard avionics must be priced such that widespread use in both commercial and general aviation aircraft is financially viable.

Slide 6

Rail Transportation Developments

- Motive Power
  - tractive effort enhancement (bulk carrier service)
  - track horse power enhancement (express service)
  - increased power-to-weight ratio
  - more fuel efficient prime movers
  - traction motors
  - new truck development
  - alternative fuels
- Operations
  - Advanced Train Control System (ATCS)
  - Driver Advice Systems (MTO/GO Transit)
- Infrastructure
  - impact load attenuation
  - grinding
  - lubrication
  - geotextiles

Slide 7

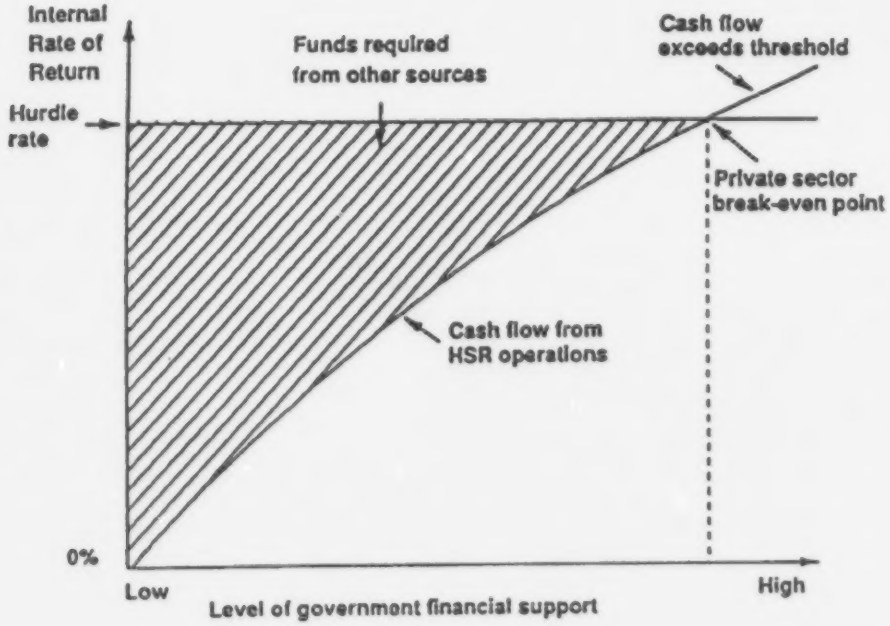
High Speed Rail
Quebec City-Windsor Corridor

Experience outside North America (Japan, France) over the past 25 years has clearly demonstrated that efficient high-speed passenger services can compete effectively for intercity traffic for trips in the 200 to 600 km range.

however

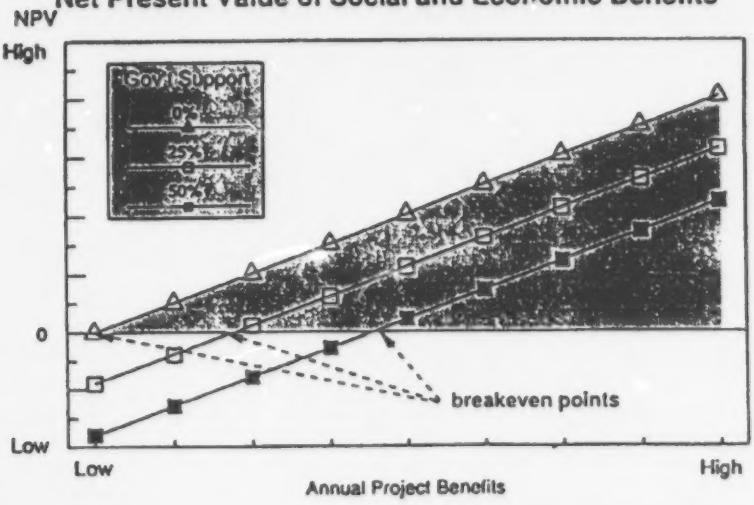
Development of high-speed rail in the Quebec City-Windsor Corridor cannot be undertaken as a purely commercial venture if a dedicated infrastructure is required.

Slide 8



Revenue Requirements From Non-Operational Sources at Different Levels of Public-Sector Investment

Slide 9



Required Levels of Economic and Social Benefits at Different Levels of Public-sector Investment

Slide 10

Corridor	Catchment (M)	Market Share Public Modes (before HSGT)	Corridor Length	Infrastructure Status (before HSGT)	Commercial Performance		
					Operating Profit	Net Recovery	Capital
SHINKANSEN							
• Tokaido	51.2	>60%	515 km	congested rail	yes	yes	yes
• New Sanyo	30.0	>60%	554 km	congested rail	yes	yes	yes
• Joetsu	8-12	>50%	270 km	some excess capacity	yes	no	no
• Tohoku	8-12	>50%	496 km	some excess capacity	yes	no	no
TGV-PSE	28.7	>50%	418 km (new line) 2041 km (all lines)	congested rail	yes	yes	yes, by 1991
Toronto-Ottawa-Montreal (VIA, 1989)	8.2	18%	592 km	ample capacity, rail, bus, some airport congestion	yes	no	no
Quebec City-Montreal	5.1	10%		as above	yes	no	no
Southwestern Ontario	6.3	14%	360 km	as above	yes	no	no

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Technology Options for the Québec City-Windsor Corridor

Intermediate Speed (140-200 km/h)

Technology	*Development Status*	*Propulsion Type*	*Maximum Speed*
F40PH	in service	medium-speed diesel-electric	155 km/h
LRC	in service	medium-speed diesel-electric	155 km/h
HST	in service (Britain)	high-speed diesel-electric	200 km/h
ANF RTG TURBO IV	in service (France)	turbine-mechanical	200 km/h (service) 225 km/h (mfg claim)
ABB Tilt-Train (Swedan)	late pre-production prototype/ early fleet production	overhead electric	200 km/h

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Technology Options for the Québec City-Windsor Corridor

High Speed (201-249 km/h)

Technology	*Development Status*	*Propulsion Type*	*Maximum Speed*
Electra CL91 (Britain)	in service	overhead electric	225 km/h
ABB Florida Train	conceptual design	overhead electric	240 km/h
Shinkansen, all series	in service	overhead electric	210-240 km/h
Florida Turbo-TGV	conceptual design	turbine-electric	225 km/h

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Technology Options for the Québec City-Windsor Corridor

Very High Speed (250-350 km/h)

Technology	*Development Status*	*Propulsion Type*	*Maximum Speed*
TGV-PSE	in service	overhead electric	270 km/h (service)
TGV-Atlantique	in service	overhead electric	300 km/h (service)
ICE	pre-revenue service fleet production	overhead electric	250 km/h (service 400 km/h (test)
Fiat ETR 450 tilt-train	in service	overhead electric	250 km/h
Fiat ETR 500 (Italy)	pre-production prototype	overhead electric	300 km/h

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Technology Options for the Québec City-Windsor Corridor

Super Speed (>350 km/h)

Technology	*Development Status*	*Propulsion Type*	*Maximum Speed*
Transrapid 07 EMS Maglev	pre-production prototype	long stator linear motor	400+ km/h (test)
JR EDS Maglev	development prototype	linear synchronous motor	500+ km/h (test)
HSST-400 EMS Maglev	conceptual design	short-stator LIM	400 km/h (mfg claim)

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High Speed Rail
Track/Guideway

Technology Considerations:

High-speed rail in the Quebec City-Windsor Corridor is technically feasible, however the impact of infrastructure requirements on financial feasibility must be examined.

- high-speed operation demands low gradients and curvatures
- subgrade must maintain alignment through freeze-thaw cycle
- positive fixation between rail and ties is required
- grade-separation must be provided (bridges, etc.)
- differing design standards in North America and Europe
- operation of non-conforming technology on existing track

Financial Considerations:

The cost of infrastructure, excluding electrfication, is the largest single component of total initial capital cost for a high-speed rail system.

- 63% to 73% of total for 200 km/h service
- 53% to 60% of total for 300 km/h service

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High Speed Rail
Motive Power Options

(in order of increasing speed capability)

- medium-speed diesel engine/electric transmission
- high-speed diesel engine/electric transmission
- gas turbine engine/mechanical transmission
- gas turbine engine/electric transmission
- electrified operation with wayside power supply
- magnetic levitation with linear motor propulsion

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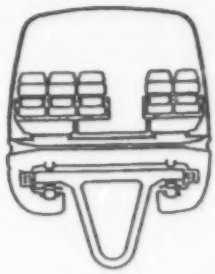
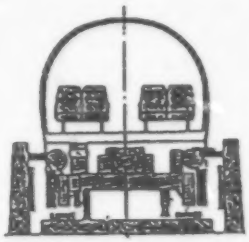
CHARACTERISTICS OF ELECTROMAGNETIC AND ELECTRODYNAMIC SUSPENSION SYSTEMS

	EMS (attraction mode)	EDS (repulsion mode)
Representative configuration		
Magnets	Iron-cored electromagnets.	Superconducting coils.
Guideway components	Laminated or solid ferromagnetic strips.	Aluminum strips or multi-turn coils.
Lift-off speed	Magnetically suspended at all speeds.	40-80 km/h.
Guideway clearance	10-15 mm	100-150 mm
Stability	Inherently unstable. Feedback control necessary to maintain dynamic stability.	Dynamically stable, but underdamped. No feedback control necessary. Secondary suspension required for good ride quality.
Compatible drive systems	Iron-cored linear synchronous motor, or linear induction motor.	Air-core linear synchronous motor.

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Advanced Train Control System

An industry driven program to implement radio-based train control systems which communicate and enforce compliance with movement authorities, signals and speed limits.

Six main functions:

- presence detection
- track and route integrity
- ancillary systems interface
- switch control
- train control
- management of train operations

Four functional modules:

Level 10 - centrailzed route and block interlocking
Level 20 - automated transmission and display of instruction
Level 30 - full train tracking
Level 40 - full field interlocking

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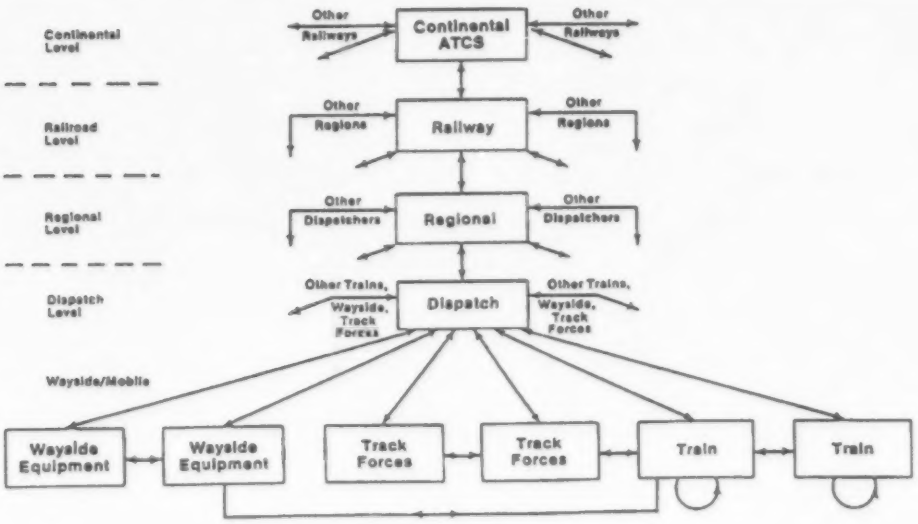
FUNDAMENTAL ATCS SYSTEMS MODEL



Source: ARINC Research Corporation

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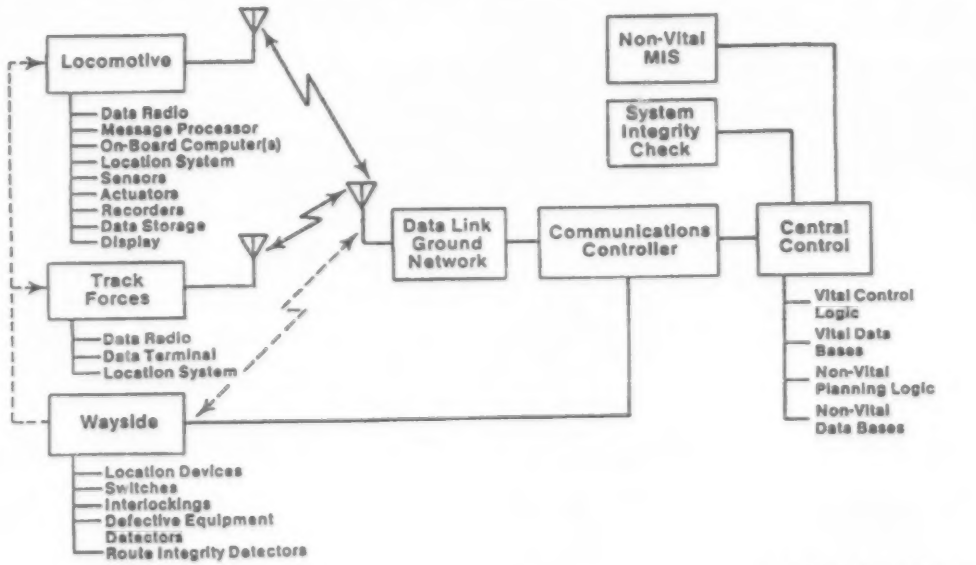
GENERAL ATCS SYSTEM ARCHITECTURE



Source: ARINC Research Corporation

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Dynamic Wheel Loads

Dynamic wheel loads play a major role in the development and propagation of track system failures.

Cause:

- wheel flats
- engine burns
- track system transitions (switches, frogs, etc..)

Effect:

- rail head corrugation on tangent track
- shelling and plastic deformation on curves
- cracked concrete ties

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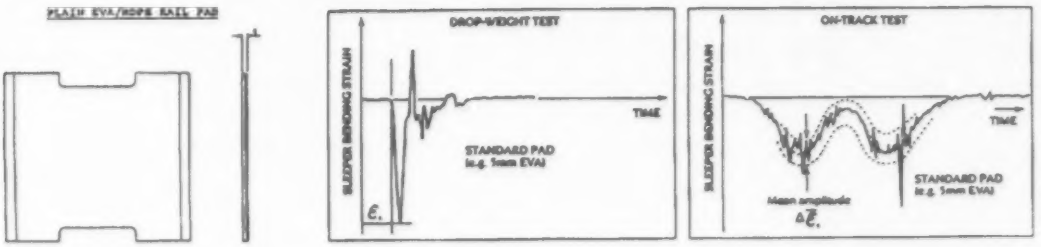
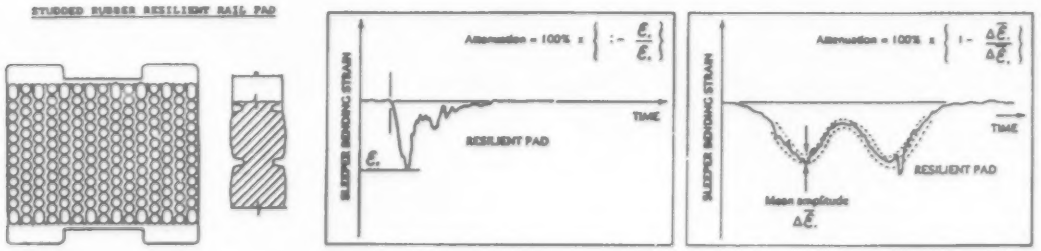
Tie Pads

• negligable impact attenuation



• up to 60% impact attenuation



Source: Pandrol International Limited

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Technology Applied To Reduce Track Wear

- Concrete Ties ("the bigger the better" philosophy)

  - more stable track
  - longer life expectancy than wood
  - better maintenance of track gauge
  - improved lateral stability (2 block tie)

  complications:
  - lack of adequate understanding of dynamic behaviour
  - severe cracking (northeast corridor) resulting from lack of resilience (improper choice of tie pad)

- Rail grinding (removes corrugations and shells)

  - intended to prolong wheel and rail life
  - lowers defect counts on rail

  complications:
  - rail head stress increased with removal of material
  - increased rate of metal attrition due to higher stress
  - if not properly applied, grinding can reduce rail life

- Gauge face lubrication

  - reduces friction thereby reducing rail head wear and prolongs rail life

  complications:
  - excess lubrication can cause derailment
  - increases propagation rate of rail surface cracks if

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What can be learned from these experiences ?

- Should examine the influence/interdependence of all track parameters on any new technology prior to adopting it on a large scale

- Must ensure that resiliency is engineered into track system infrastructures to accomodate unforseen requirements and increasing performance demands

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Corridor	Catchment (M)	Market Share Public Modes (before HSGT)	Corridor Length	Topographical Geotechnical Conditions: Infrastructure Status (before HSGT)	% Tunnels	% Bridges	Max. Grade	Commercial Performance: Operating Profit	Net Profit	Capital Recovery
SHINKANSEN										
• Tokaido	51.2	>60%	515 km	congested rail	13	11	2.0	yes	yes	yes
• New Sanyo	30.0	>60%	554 km	congested rail	51	9	1.5%	yes	yes	yes
• Joetsu	8-12	>50%	270 km	some excess capacity	39	11	1.5	yes	no	no
• Tohoku	8-12	>50%	496 km	some excess capacity	23	16	1.5	yes	no	no
TGV-PSE	28.7	>50%	416 km (new line) 2041 km (all lines)	contested rail	0	0.46	3.5%	yes	yes	yes, by 1991
Toronto-Ottawa-Montreal (VIA, 1989)	8.2	18%	592 km	ample capacity, rail, bus, some airport congestion	0	1.2	3.0%	yes	no	no
Quebec City-Montreal	5.1	10%		as above	0	<1	n/a	yes	no	no
South-western Ontario	6.3	14%	360 km	as above	0	<1	n/a	yes	no	no

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Technology Options for the Quebec City-Windsor Corridor

Technology Class	Technology	Development Status	Propulsion Type	Maximum Speed	Compatible with Existing CN/CP Track and Operating Regulations	Shortest Time to Deploy
Intermediate-speed (140-200 km/h)	F40PH	in service	medium-speed diesel-electric	155 km/h	yes	1 year
	LRC	in service	medium-speed diesel-electric	155 km/h (service)	yes; 1	1 year
	HST	in service (Britain)	high-speed diesel-electric	200 km/h (mfg claim) 200 km/h	yes; but 1,2	2-3 years
	ANF RTG TURBO IV	in service (France)	turbine-mechanical	200 km/h (service) 225 km/h (mfg claim)	yes; but 1,2	1½-2 years
	ABB Tilt-Train (Sweden)	late pre-production prototype/early fleet production	overhead electric	200 km/h	no; 1,2,3	5-8 years

Notes: 1. Speed limited to 155 km/h due to at-grade road/rail crossings
2. Vehicle does not meet existing North American (FRA) structural standards for compressive (buff-load) strength.
3. Requires major investment in overhead electrification, modifications to signal system.

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Technology Options for the Quebec City-Windsor Corridor

Technology Class	Technology	Development Status	Propulsion Type	Maximum Speed	Compatible with Existing CN/CP Track and Operating Regulations	Shortest Time to Deploy
High-speed (201-249 km/h)	Electra CL91 (Britain)	in service	overhead electric	225 km/h	no; 1,2,3	5-8 years
	ABB Florida Train	conceptual design	overhead electric	240 km/h	no; 1,2,3	5-8 years
	Shinkansen, all series	in service	overhead electric	210-240 km/h	no; 1,2,3	5-8 years
	Florida Turbo-TGV	conceptual design	turbine-electric	225 km/h	yes; but 1,2	2-3 years

Notes: 1. Speed limited to 155 km/h due to at-grade road/rail crossings
2. Vehicle does not meet existing North American (FRA) structural standards for compressive (buff-load) strength.
3. Requires major investment in overhead electrification, modifications to signal system.

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Technology Options for the Quebec City-Windsor Corridor

Technology Class	Technology	Development Status	Propulsion Type	Maximum Speed	Compatible with Existing CN/CP Track and Operating Regulations	Shortest Time to Deploy
Very High-Speed (250-350 km/h)	TGV-PSE	in service	overhead electric	270 km/h (service)	no; 1,2,3	5-8 years
	TGV-Atlantique	in service	overhead electric	300 km/h (service) 400 km/h (test)	no; 1,2,3	5-8 years
	ICE	pre-revenue service fleet production	overhead electric	250 km/h (service) 400 km/h (test)	no; 1,2,3	5-8 years
	Fiat ETR450 tilt-train	in service	overhead electric	250 km/h	no; 1,2,3	5-8 years
	Fiat ETR 500 (Italy)	pre-production prototype	overhead electric	300 km/h	no; 1,2,3	5-8 years

Notes: 1. Speed limited to 155 km/h due to at-grade road/rail crossings
2. Vehicle does not meet existing North American (FRA) structural standards for compressive (buff-load) strength.
3. Requires major investment in overhead electrification, modifications to signal system.

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Technology Options for the Quebec City-Windsor Corridor

Technology Class	Technology	Development Status	Propulsion Type	Maximum Speed	Compatible with Existing CN/CP Track and Operating Regulations	Shortest Time to Deploy
Superspeed (>350 km/h)	Transrapid 07 EMS Maglev	pre-production prototype	long stator linear motor	400+ km/h (test)	no; 2,3,4	6-10 years
	JR EDS Maglev	development prototype	linear synchronous motor	500+ km/h (test)	no; 2,3,4	8-12 years
	HSST-400 EMS Maglev	conceptual design	short-stator LIM	400+ km/h (mfg claim)	no; 2,3,4	10-15 years

Notes: 1. Speed limited to 155 km/h due to at-grade road/rail crossings
2. Vehicle does not meet existing North American (FRA) structural standards for compressive (buff-load) strength.
3. Requires major investment in overhead electrification, modifications to signal system.
4. Requires completely separate infrastructure.

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MINISTER'S ADDRESS

delivered by

Gordon Miller

Gordon Miller is Parliamentary Assistant to the Minister of Transportation. Mr. Miller is the provincial Member of Parliament for Norfolk riding and a member of the Standing Committee on Resources Development.

Good afternoon, ladies and gentlemen. I am pleased to be here today on behalf of your Minister, William Wrye. Mr. Wrye regrets he was unable to attend this important conference, because he believes, as I do, that the kind of research and development initiatives being discussed here will be crucial to our well-being and prosperity in the coming years. Conferences like this one encourage the sharing of ideas and theories about emerging technologies, and lead to the forging of a common bond, one that will allow us to improve today's transportation systems and plan for the needs of tomorrow.

The ministry is prepared to support your proposals, ideas, and visions for the future. If it makes sense to our transportation network and the people of Ontario, MTO will get behind it.

Scientific advances are being made at an unprecedented rate. The industrialized countries of the world are caught up in a race to find newer and more innovative technologies to give them the upper hand in a fiercely competitive global marketplace.

The technical developments taking place around us have had a profound impact on the way we work and play. Computers are the tools of the trade for most office workers these days, and our children spend an increasing amount of their time with Nintendo games and CD players. In fact, there are few aspects of our daily lives that haven't been touched by technology, including the way we travel.

As I was considering what I would speak to you about today, it occurred to me that, if Henry Ford were alive today, he would marvel at the changes that have taken place over the last century. When his Model T was logging its first miles, even he couldn't have anticipated the wide-reaching and fundamental changes the automobile would have on our society. Yet, no single piece of machinery has been more instrumental in helping us to develop our cities, open up new markets for our products, and make our lives easier and more enjoyable.

The irony is that the automobile's success has turned out to have a downside, as well. Today, the world is faced with an oversupply of motor vehicles, and concerns about congestion and pollution are mounting every day. As transportation specialists, we have a responsibility to tackle these concerns. Our efforts to improve the quality of life in Ontario require us to engage in research and development activities that have not just short-term benefits, but also meet the needs of future generations.

The purpose of this conference is to look ahead to new horizons and to review and assess our ministry's research strategies, so that we are equipped to deal with the opportunities ahead.

Our keynote speaker last night, Professor Valaskakis, and our plenary speaker this morning, Dr. John, alluded to some of the social and technological changes that will take place in the next decade and beyond. More than 10 years ago, Professor Valaskakis predicted many of the issues we are facing today. He talked about how these developments are affecting us and the opportunities they present for engineers.

The speakers this morning outlined some of the most promising technologies, smart highways, the wired city, automated transitways and guideways. To the public at large, they sound like subjects for a science fiction

novel, but we know they're not far from becoming realities. The challenge for us is to gain a competitive advantage through the understanding and application of progressive ideas and technology. We will need to be on the leading edge of these developments if we are to keep pace with our competitors throughout the world.

Let's look at Japan as an example. It now produces more than two-thirds of all the industrial robots used worldwide, and can certainly boast the most technologically literate population, since education has become somewhat of a national obsession. These values are reinforced by parental guidance, community leaders, and employment strategies in both industry and government. There is no doubt Canadians must go through a scientific and technological awakening. It has begun with new attitudes and an acceptance that we cannot be satisfied with the technological and trade status quo. It is no longer a viable long-term alternative.

We are gradually beginning to shed our historic approach of relying solely on government and university research, and are looking more to private sector and commercial innovation. Much of the success won by Canadian technology has been attained through a strategy of focusing on products that fill a particular need or market niche. I don't believe it would make much sense to compete with the super powers in rocket-building. Instead, we have concentrated on building a highly specialized product: the Canadarm used in the U.S. space shuttle program, and we are doing it very well. Our approach in other areas should, perhaps, be the same.

Over the past few years, a new relationship has been established between Canadian universities and the private sector for the purposes of fundraising, research, and development. To make it work, the private sector has to adopt the long-term view that it makes sense to invest in the future. For its part, the academic world must, in turn, establish stronger links with industry. By creating a team effort among government, private industry, and academia, we have the potential to become world-class performers in any field of technology we choose.

The government is not just talking about partnerships. We are investing in them. We have launched initiatives such as the Premier's Council on Technology and the one $billion, ten-year Technology Fund, the University Research Incentive Fund, and the Growth Ventures program to support the growth of small and medium-sized companies. The Council has also recommended the government share risks with companies on the threshold of becoming multi-nationals.

But, if we are truly interested in achieving something meaningful, we need to work as partners on a global basis, harnessing technology with our colleagues in Japan, Europe, and south of the border. We all have a role to play.

I am proud to say that the Ministry of Transportation has consistently been in the forefront of technological changes, not just in Canada, but often throughout North America. We have played a leading role in bringing new ideas to fruition, examples of which are not hard to find. Let's take our work in the area of natural gas buses. While we continue to research all alternative fuels, the favourable properties of natural gas makes it of particular interest in some markets, particularly transit. Not only does it burn cleanly, it's a cheap, plentiful fuel and contributes less to the greenhouse effect. So far, the marketplace is suggesting we are on the right track. An Ontario company is actually producing natural gas buses, which has generated interest world-wide. U.S. orders for these buses are now coming in.

MTO is also sponsoring three pilot projects to test natural gas-powered buses under actual operating conditions in Toronto, Hamilton, and Mississauga. We hope these tests will demonstrate conclusively that environmentally friendly transportation can also be both cost-efficient and effective.

At the same time, our ministry has taken the initiative to support the design of first-class transportation for disabled persons. We have been proud to support the development of the ORION II bus, which is built right here in Ontario and has found success throughout North America and also in Europe. These innovative vehicles, which kneel to curb height, provide a level of comfort

and convenience that was not possible with converted vans and other vehicles.

In a similar vein, we are trying to help disabled individuals who have little or no use of their hands to enjoy the freedom that comes with driving their own cars. To that end, we have joined forces with a local rehabilitation centre to design an interface unit which will replace manual controls.

Balancing the divergent needs of people and municipalities is an ongoing challenge for the ministry. For example, in this province, traffic congestion has traditionally been considered an urban challenge, affecting primarily the Greater Toronto Area where more than one-third of our total provincial population of over 10 million lives and works. We are acutely aware, however, that this issue is increasingly affecting the economic competitiveness and quality of life in all parts of Ontario.

With automobile ownership doubling over the past 20 years, our existing infrastructure is at or exceeding capacity in many areas. While there are no instant remedies, a number of technologies have been and are being developed that promise to improve safety and efficiency.

One such project is the Communication Information System (CIS), which we developed over a ten-year period with the Toronto Transit Commission in the 1970s and 80s. A computerized vehicle monitoring and control process allows operators to pinpoint the exact location of a vehicle at any given time. It also gives them the ability to adjust schedules when necessary and communicate with drivers in an emergency. The system is now being installed on over a thousand TTC surface vehicles. The benefits so far include cost savings, service improvements, and enhanced passenger and operator safety and security.

We are now evaluating a similar project to improve the efficiency of transit operations in other Ontario cities. The Automatic Vehicle Location and Control System allows us to collect information about vehicle location, as well as other operational data. Like CIS, this system can provide useful monitoring, re-scheduling and safety benefits.

Another exciting initiative is the Freeway Traffic Management System, first introduced in 1975 on the Queen Elizabeth Way. It's a completely new state of the art being installed along the Metro Toronto stretch of Highway 401, one of North America's busiest roads.

We are also, in conjunction with private industry, testing a Wide Area Vehicle Monitoring System that applies satellite communications and navigation technology to truck fleet management. This system is expected to help the trucking industry bring about substantial efficiency improvements in fleet dispatching and management.

While we have all heard of high-tech robotics being used in industrial assembly lines, they are not commonly associated with transportation equipment maintenance. The ministry has harnessed this technology and developed a full-scale robotic system for cleaning the underside of subway cars, and a project is now underway in Kitchener using robots to clean buses.

For crews working directly on busy roadways, there are very real risks. An Ontario invention, the Automated Road Analyzer, or ARAN, for short, addresses these dangers. The ministry's commitment to purchase the first two vehicles produced has provided much-needed support for this innovative new technology.

Everyone knows economic success depends on a solid infrastructure. In that respect, the Ministry of Transportation's track record in providing sophisticated road, rail, water, and air transportation routes has contributed to Ontario's rapid growth and current status as a leader in Canada. We have maintained this position through our own research and development activities, as well as by working with other governments, research organizations, and private industry.

In the past, our primary objective was to create a large infrastructure, to fuel the economy. The future, however, presents many new and complex challenges. In the coming years, we will be faced with new challenges to develop transportation that serves

economic and environmental goals. Given the monumental changes that have taken place around the world in the past year, I believe international resources will soon shift from the arms race to the environment, just as they did after World War II.

This increased focus on environmental issues will undoubtedly change the way we think. But society has demonstrated it can adapt to a shift in global priorities. Think back to the energy crisis of the 70s, people learned to conserve. By making more creative use of our resources and planning tools, we will be able to shape an exciting and healthy world for our grandchildren. In the coming years, we will need technology to help solve the complex issues we face, not just within the transportation sector, but society as a whole.

We have seen a number of science fiction dreams come true in our lifetime. Inventions such as on-board computers and cellular phones, gadgets which just a few short years ago seemed like "pie in the sky." As I said earlier, Henry Ford would have been astonished at the sophistication and precision of these devices. The future of other people-friendly technology is unlimited, if we work together.

I wish you an enjoyable afternoon and hope that the exchanges you've had today with colleagues from various sectors of the industry have been both productive and inspiring.

DEALING WITH CLIMATE CHANGE:

AN AGENDA FOR THE NEXT DECADE

H.G. Hengeveld

Henry Hengeveld is Advisor on Carbon Dioxide Related Matters at the Canadian Climate Centre, Atmospheric Environment Service of Environment Canada.

In June 1988, a large group of policy-makers, scientists, economists, legal and other experts from 46 nations met in Toronto to participate in the World Conference on the Changing Atmosphere. At the conclusion of that watershed meeting, the participants declared that "humanity is conducting an unintended, uncontrolled globally pervasiv experiment whose ultimate consequences could be second only to a global nuclear war." They were referring to the rapid change in the composition of the earth's atmosphere due to human release of pollutants.

During the year since the Toronto conference, a number of major international statements supported by senior level politicians have declared atmospheric change, and particularly climate warming, a major global environmental issue demanding political action now. Most recently, the World Energy Conference, meeting in Montreal in September, placed unprecedented importance on the issue of climate warming in its deliberation on energy for tomorrow. Why this rather sudden and intense political and private sector interest in problems of the earth's atmosphere? How real is the threat to the atmosphere? How certain is the background science and can it justify the concern? If so, what are the implications, and how should we respond?

This presentation will briefly review what the background science can and cannot already say about this issue and, based on the many recommendations that have come forth, suggest some major themes and strategies for responding to it.

Evidence for Change

Regular measurements of atmospheric concentrations of CO_2 at numerous stations around the world show a global increase of 11% over the past 30 years. When compared with information obtained from air bubbles fossilized within the Antarctic ice cap, it appears that current values are about 2025% higher than the previous highest values during at least the past 160 000 years. The principal source of additional accumulation of CO_2 into the atmosphere appears to be the release of carbon as carbon dioxide during the combustion of fossil fuels. The destruction of vast tracts of tropical timberland to make way for agricultural development appears to be a significant secondary source.

Other atmospheric constituents important to climate are also changing rapidly. Methane concentrations, monitored since the early 1970s, are increasing at about 1.1% each year and are already more than double those of pre-industrial times. Although increased global populations of cattle and acreage of rice paddies are believed to be primary sources, release of methane during coal and gas extraction processes and biomass burning are estimated to account for about 40% of the increase. Nitrous oxide is also increasing at 0.3% per year, with an estimated 50% contributed by fossil fuel combustion. Surface concentrations of ozone are increasing in urban areas, largely as a by-product of energy use for transportation. Other gases such as chlorofluorcarbons, although as yet low in concentrations, are in many cases increasing very rapidly.

The above greenhouse gases have several common features. They are all climatically important gases that already have an abundance sufficient to significantly influence the heat radiation balance of the climate system. They are all increasing in concentration due to human activities. Finally, most are increasing in concentration at least partly due to emissions from the extraction and combustion of fossil fuels.

Basis for Concern

Greenhouse gases collectively behave as an insulating blanket around the planet. Their effect on the incoming solar heat energy which fuels the earth's climate system is minimal. However, their combined influence on the outgoing heat radiation, emitted from the earth's surface and lower atmosphere towards space to cool off the climate system, is large. By absorbing and returning much of this outgoing radiation, they effectively trap heat within the lower atmosphere. This "greenhouse effect" is naturally occurring and essential to life on earth. Without it, the earth's surface would be more than 30°C colder. Changing the concentrations of greenhouse gases in the atmosphere will in turn affect the effectiveness of this greenhouse effect.

Projections of future $C0_2$ emissions into the atmosphere clearly suggest at minimum an eventual doubling of atmospheric $C0_2$ concentrations over pre-industrial levels. However, the timing of such doubling remains uncertain, since long-term future human behaviour with respect to energy consumption is largely unpredictable.

Concentrations of other greenhouse gases are also likely to increase significantly in future decades, adding to the climatic effects of rising $C0_2$ levels. A combined effect on climate equivalent to a doubling of $C0_2$ appears possible as early as 2030 AD, and highly probable by 2050 AD.

Atmospheric modelers do not as yet agree on the magnitude of the net climatic changes that would result from an enhanced greenhouse effect. Nor do they agree on the regional characteristics of such changes. However, there is a consensus that such changes will be large, significantly amplified towards polar regions in fall, winter and spring seasons and accompanied by a major adjustment in global rainfall patterns. The range of estimates for the average global surface temperature rise for a $C0_2$ doubling varies from 1°C to 5°C and higher. Most model results also suggest a migration of mid-latitude North American storm tracking northward, resulting in a drier mid-continent and a wetter sub-Arctic.

Climate trends of the past decade indicate that a global climate warming is already in progress. Global temperatures have warmed by 0.4 to 0.5°C over the last century. The six warmest years over that time period have occurred in the 1980s. Although this trend is consistent with model predictions of expected response of climate to changes in greenhouse gas concentrations to date, they are also still within the realms of long-term climate variability, and could be explained by combinations of natural causes for change. While some scientists are already preparing to give the credit to the enhanced greenhouse effect, most feel such conclusions are premature.

Numerous studies have attempted to evaluate how the above changes, should they happen, might affect natural global ecosystems and humans. Some of the consequences are potentially positive. Direct effects of higher $C0_2$ levels on plants, for example, are beneficial for improved growth and drought tolerance. Warmer temperatures will improve growing seasons in cooler climates, while making polar regions more accessible to marine transportation. However there is great cause for concern in other domains. With almost 50% of the world's human population located along the ocean coastlines, the possibility of a one metre or more rise in sea levels has very ominous implications, particularly for low-lying countries such as Bangladesh, Egypt, the Maldives, and the Netherlands. Redistribution of rainfall will decrease drought stress in some areas and turn others into deserts, dramatically changing the global pattern of food production and distribution. Slow forest response to climate shifts may result in large-scale dieback along the warm margins of current ecosystems. Heat stress, increased disease, poorer water quality, and more frequent severe tropical storms could have major implications for human health and life. Of greatest concern is that the change may be too rapid to make adaptation possible, hence a high risk for catastrophic events.

Responding to the Challenge

Numerous international gatherings have attempted to address this question in recent years, including the conference held in Toronto in 1988. The consensus appears to be that we must simultaneously attempt to further our research to improve the understanding, prepare for those climate changes that may already be inevitable, and move internationally and domestically to

"limit, reduce and, as far as possible, prevent" further climate warming. International law becomes a factor in the second action and a key element in the last. Common conclusions in the international discussion suggest that such legal intervention:

- is inevitably necessary and achievable.

- must be fair and equitable. Developing nations must be an integral part of the solution, but industrialized countries must bear the primary technological and financial responsibilities for reducing emissions of atmospheric pollutants. After all, over 50% of global $C0_2$ emissions presently come from OECD countries, but all nations will suffer the consequences.

- must be co-ordinated and co-operative.

This presents a real challenge for international law. No longer are we dealing with bilateral transgressions and damages that can be examined on an aggressor/claimant basis, but with an issue where all nations are, more or less, both aggressor and claimant. What is now needed is a much broader umbrella framework convention that can deal with the atmosphere on a global and more holistic basis and that can appeal to all nations on a fair and equitable basis. Canada is now collaborating with other countries in drafting proposed elements for a global convention on climate change for use in discussions at international meetings.

Meanwhile, domestically we also need to put our house in order. While Canada contributes only 2% of the global emissions of $C0_2$, it is fourth highest internationally in per capita emissions. Hence the need for national action to reduce our emissions, primarily through improving our energy efficiency, and to promote a public awareness of the issues and implications. In many respects, the latter is the most important, since it is the motivator that should simultaneously remove complacency and avoid hysteria. Conferences, meetings, public hearings, and factual literature are required to educate and seek the involvement of scientists, policy-makers, and public alike. Herein lie the foundations for action.

Finally, a few comments on the implication at the regional level, particularly for transportation. Where do we, as citizens of Ontario, fit in? The answer lies in the maxim, "think globally, act locally." First, there is the question of understanding the implication of climate change. While studies under the auspices of the Canadian Climate Program have helped to develop a very crude image of what climate change may really mean, more intensive investigations into sensitivities of our daily activities to climate variances are needed. What, for example, are the implications of climate change for driving conditions in Ontario, or for road maintenance? How will it affect urban air pollution?

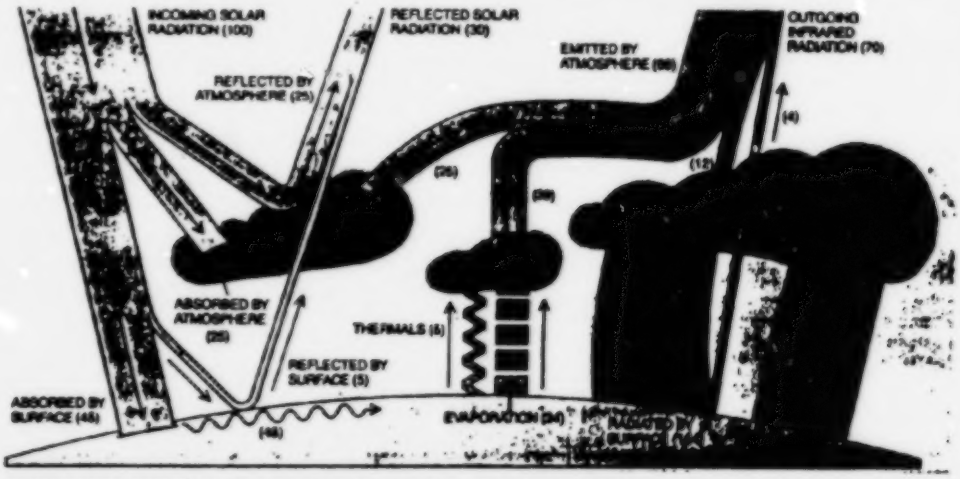
Second, we must start to take mitigative action to adapt to climate change that already appears inevitable. In some activities we must wait for greater certainty. In others, such as reforestation programs, we can ill afford to delay, for the trees we plant today will live to see a different climate.

Third, we need to begin to do our part locally in limiting the greenhouse gas emissions. Not only are we as individuals among the worst polluters in the world, but our energy inefficiency puts us at great economic disadvantage. Transportation is a major source of these emissions. In Ontario, for example, one third of its $C0_2$ emissions from combustion of fossil fuels comes from the transportation sector. Of that, 80% is emitted on the roads.

Finally, we must do our part in promoting awareness, though our schools, through interaction with the public, and through programs such as that recently launched by Ontario Hydro to reduce energy demand. As Canada's energy ministers agreed in August, "the consequences of inaction are unacceptable."

Climate Change

- Most complex environmental issue
- Man-made/natural causes
- International/domestic stakeholders
- Solutions are difficult



GREENHOUSE EFFECT arises because the earth's atmosphere tends to trap heat near the surface. Carbon dioxide, water vapor and other gases are relatively transparent to the visible and near-infrared wavelengths (*blue*) that carry most of the energy of sunlight, but they absorb more efficiently the longer, infrared wavelengths (*red*) emitted by the earth. Most of this energy is radiated back downward (*dark red*). Hence an increase in the atmospheric concentration of greenhouse gases tends to warm the surface.

Causes Of Climate Change

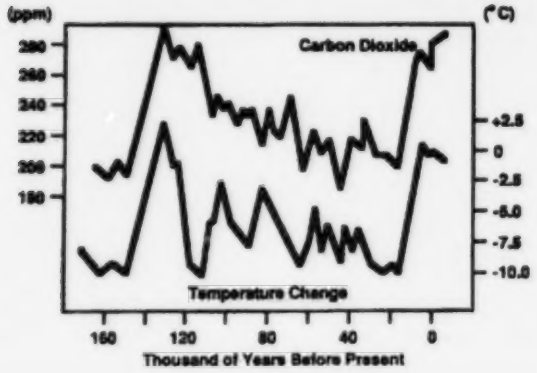
Natural Causes

- Orbital change (cooling)
  - less than .1C/100 yrs
- Volcanic (cooling)
  - up to .4C/1-2 yrs
- Solar (quasi-periodic)
  - from -0.2C to +0.2C

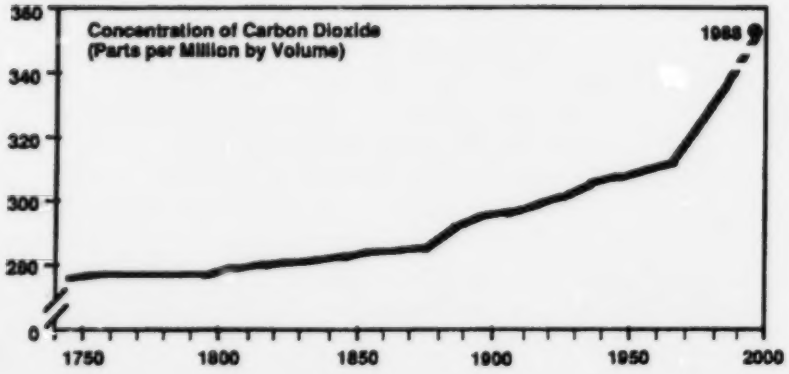
Man-Made Causes

- Greenhouse effect - warming of 1.5 - 5.0 C (doubling of CO_2)
- Other Causes - uncertain

Variation Of Global Temperature And CO_2 Over Last 160,000 Years

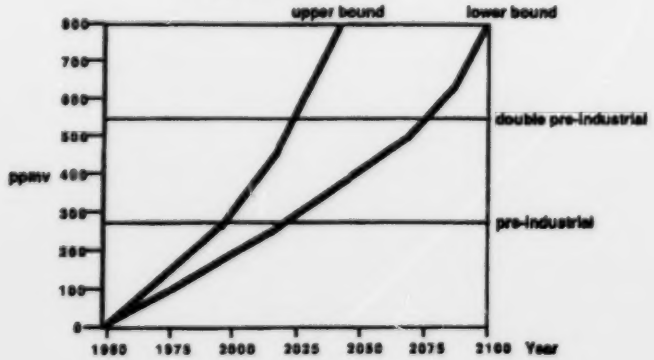


CO_2 Trends - last 200 years

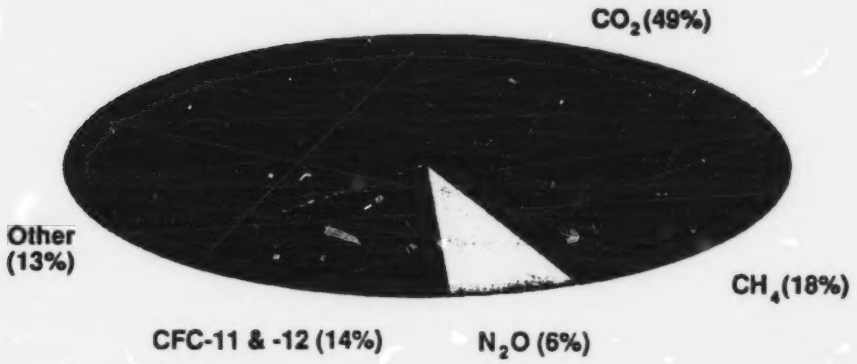


Scenarios For Future Concentrations Of Atmospheric Greenhouse Gases

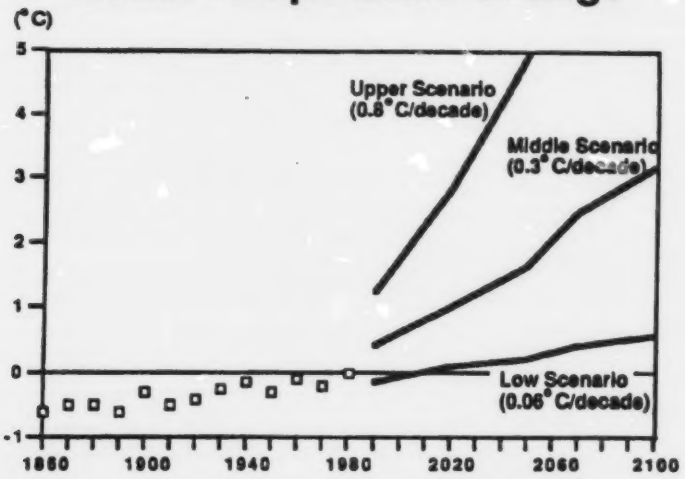
(CO_2 Equivalent Values)



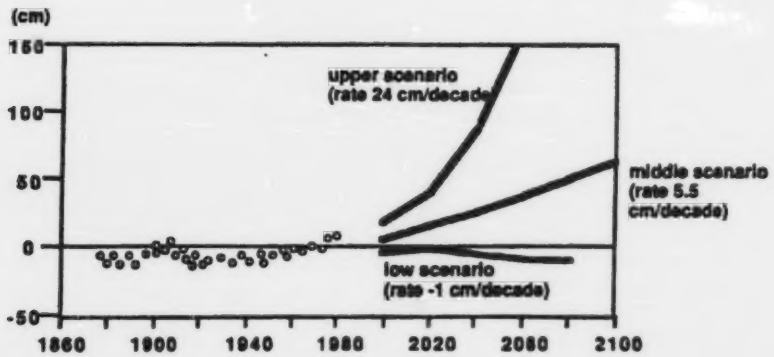
Greenhouse Gas Contributions To Global Warming



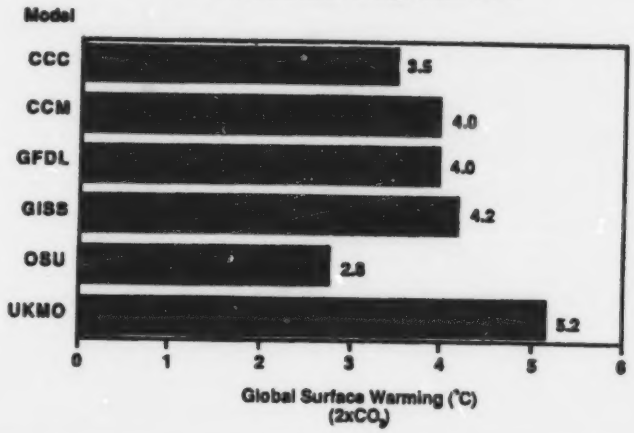
Global Temperature Change

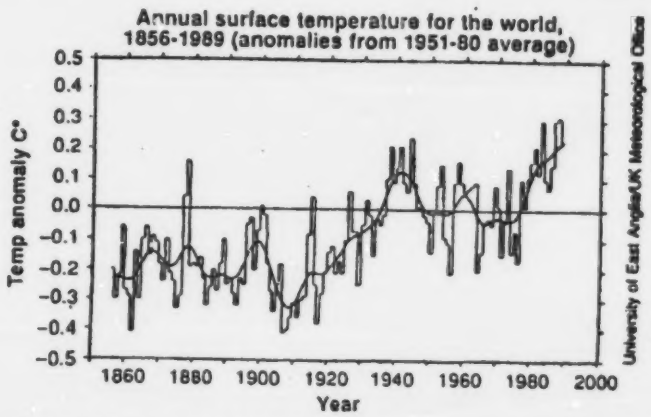


Future Sea Level Trends



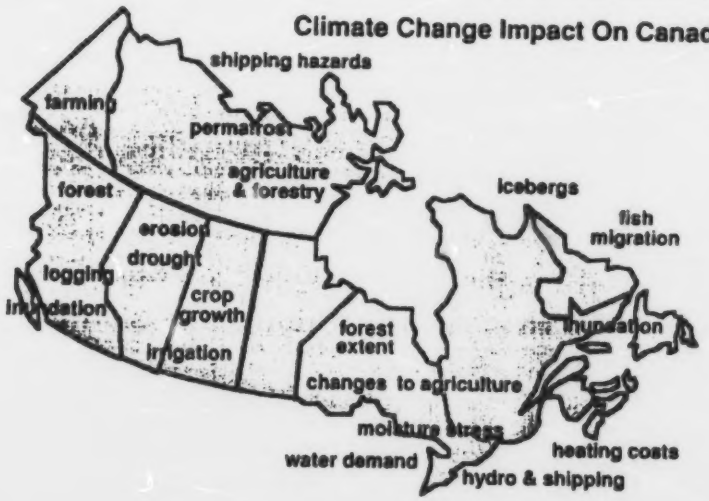
Comparison Of Climate Model Projections For Doubled CO_2 Climate



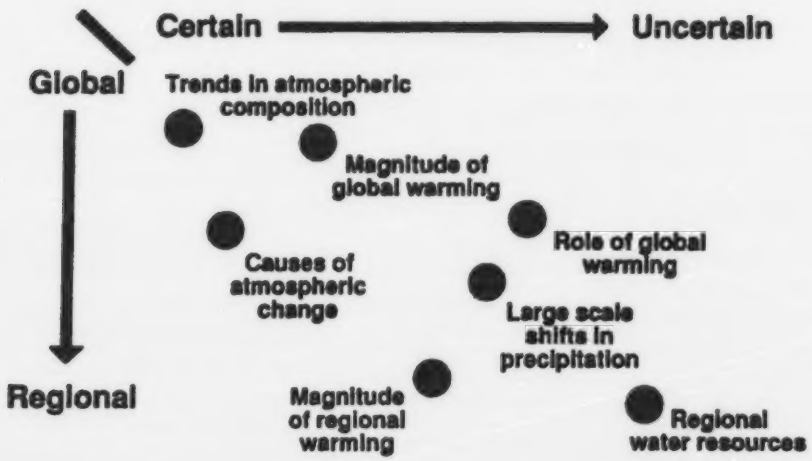


One very small step. *At 0.23°C above the mean, the 1989 global temperature falls short of a record but maintains the warming trend of the past 15 years.*

Climate Change Impact On Canada

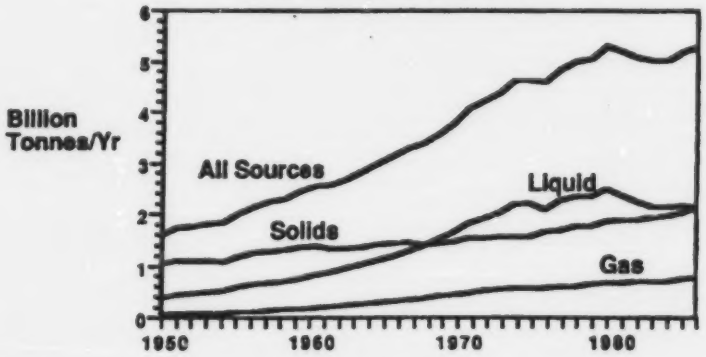


State Of Understanding



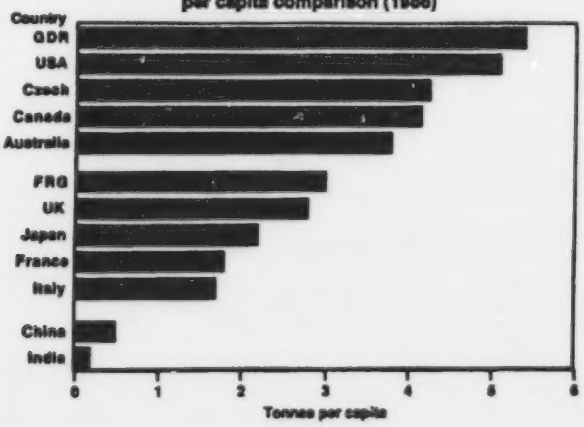
Global CO_2 Emissions From Fossil Fuel Combustion

(incl. Cement Production)

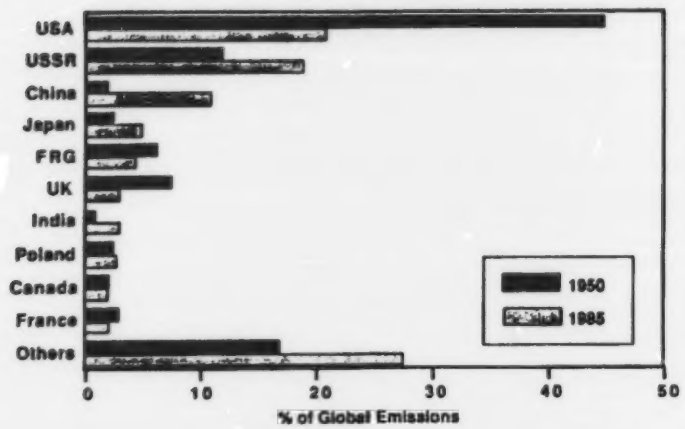


Fossil Fuel CO_2 Production

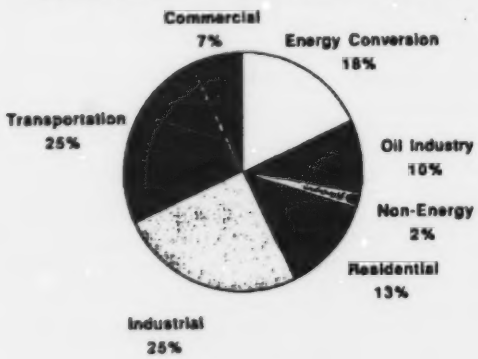
per capita comparison (1986)



Contributors To Global CO_2



CO_2 Emissions in Canada By Economic Sector 1987



AGENDA FOR THE NEXT DECADE

RESEARCH!

REDUCE THE UNCERTAINTIES
FOCUS ON MODELS
DEVELOP TOOLS FOR ASSESSING IMPACTS
UNDERSTAND RESPONSE OPTIONS

LIMITATION!

INTERNATIONAL COOPERATION
LOCAL ACTION
DO THE OBVIOUS AND EASIEST FIRST

ANTICIPATORY ADAPTATION!

WHERE COST ANALYSIS JUSTIFIES

EDUCATE!

PUBLIC
INSTITUTIONS
BOARDROOMS

ENVIRONMENTAL POLICY

MEETING THE CHALLENGE OF GLOBAL WARMING

Penny Gotzaman

Penny Gotzaman is Assistant Director of Economic Analysis, Policy Directorate of Environment Canada. Ms Gotazaman is former Director of the Economic and Corporate Analysis Division in the Energy Policy Branch of the Department of Energy, Mines and Resources.

It is a pleasure to be here today to speak to you on what is a major environmental policy issue facing Canada and the rest of the world. Global warming is one of the most complex environmental issues. It is also one of the most difficult socio-economic issues.

I am going to focus on the Government of Canada's overall approach to resolving environmental problems:

- how our approach to global warming in particular relates to actions being taken by other countries
- the implications for Canada
- the challenges faced by the transportation sector.

Environmental Policy

Over the past months, the Government of Canada has worked towards developing a strategy for addressing domestic and global environmental problems. We are soon going to launch an extensive consultations process on our proposed approach. Following these consultations, the Government of Canada will come forward – likely some time in the fall, with an Environmental Agenda.

The Environmental Agenda will do two things. It will formalize the federal government's long-term strategy for addressing environmental problems – a strategy which will move Canada from reacting to environmental crises to anticipating and preventing them. It will also introduce specific initiatives to enhance the quality of the environment.

The environmental strategy is based on the diagnosis that the root of environmental problems is the failure of all of us as individuals, in our business lives, and through our political institutions to fully take the environmental consequences of our actions into account as a matter of course in our daily decisions. It stands to reason that, to effectively resolve our environmental problems, we need to correct for this failure in decision-making. In order to do so, all levels of society will need to make fundamental changes in the way they do things.

Three elements are necessary to make these fundamental changes. First, we must improve the inputs into the decisions we make. Second, we must change decision-making processes and institutions. And third, we need to strengthen and build partnerships.

Five key factors underlie better environmental decision-making:

- Better science is fundamental. Science is key to a better understanding of environmental problems, to finding solutions, to sound policy and regulations, and to the development of "cleaner" technologies. Hence the federal government has developed measures which will provide a strong scientific base upon which to make environmental decisions.

- Nowhere is the importance of science more evident than in the case of global warming. There is still scientific uncertainty surrounding the greenhouse effect. There is also uncertainty about the relative greenhouse effects of the emissions of various gases (carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons (CFCs), as each has different characteristics with respect to factors such as how well they absorb and radiate infrared radiation, and how long they reside in the atmosphere.

- The uncertainties surrounding the greenhouse effect do not mean we should not take action to mitigate it – there is substantial evidence that global warming is a highly probable and serious problem. However, a better understanding of the problem would assist in developing a policy response. For instance, from a scientific perspective, the policy response should focus on all of the greenhouse gases – in order for it to do so, there is a need for science to devise an equivalency among them.

- Good information is another important input into decisions. It is important that governments and the public have ready access to quality, easily understood, objective measures on the state of the environment. Such measures provide a sound basis for making and evaluating decisions. The federal government has therefore addressed means of ensuring that quality environmental information is both generated and made readily available to all Canadians.

- Better education is a third. An environmentally educated population is more likely to take the environmental consequences of its actions into account, to demand the same of all sectors of society, and to have the expertise to resolve complex technical issues. We have therefore addressed ways of increasing environmental literacy, both formally through the school system, and informally through means such as the media.

In addition, governments can take two direct measures to encourage society to factor environmental considerations into decisions:

- Legislative and regulatory instruments set rules regarding the use of, and access to, the environment.

- And economic incentives that reflect environmental costs give decision-makers the financial incentive to take the environment into account.

We have looked closely at the scope for strengthening regulations and their enforcement, and will be taking action in this regard. We are also seriously exploring the possible role of economic incentives as complements and/or substitutes for environmental regulation. Economic incentives are a relatively untried area in Canada, and will require further work to fully assess the merits of implementing them in Canada.

Improving these inputs to decision-making will not be enough to bring about fundamental changes at all levels of society. Environmental factors must also be formally recognized as essential decision-making criteria within governments and the private sector.

Governments as policy-makers and businesses can have a profound impact on the environment. Governments must therefore ensure that their processes fully integrate environmental factors into decisions on new policies, programs, and projects; that they modify existing ones to minimize unintended environmental consequences; and that their business practices are consistent with sound environmental practices. The federal government is going to take measures to "put its house in order."

For its part, the private sector must take the responsibility of factoring environmental considerations into their day-to-day and corporate planning decisions in the same way as they weigh financial factors.

Finally, better decision-making will require co-operative efforts among all levels of society and all levels of government. Domestically, continued federal/provincial co-operation, and the participation of the private sector, will be essential. Internationally, co-operation will be critical to resolving complex global environmental problems. For no other environmental problem is the need for co-ordinated international action more evident than in the case of global warming.

The federal government has worked towards developing specific approaches to improve the three elements of better decision-making – better inputs, better processes and institutions, and partnerships. The views of the provinces, industry, environmental groups, and the general public will be sought in the consultations process I mentioned earlier.

Global Warming

Achieving the co-ordinated international action required for a lasting solution to global warming is a tremendous challenge.

Action has already been initiated. Last year, Canada, along with 23 other countries, signed the Hague Declaration. The declaration outlines how nations could work together to solve the problem of global warming. A key part of it is the recognition of the need for a global convention on climate change.

In a subsequent meeting of government ministers from 76 countries in November 1989 in the Netherlands, ministers emphasized the importance of establishing quantified targets and schedules to limit or reduce the emissions of greenhouse gases. It was recognized that there is a need to stabilize greenhouse gas emissions while ensuring stable development of the world economy. Industrialized countries agreed that stabilization should be achieved by them as soon as possible.

The process gets more difficult from here. First, a framework convention must be negotiated. The convention would likely formally express international concern about the problem; recognize the need for action; and provide a framework for protocols, including a protocol on explicit measures or targets for reducing emissions of greenhouse gases. Second, the protocols must be negotiated – countries must agree on the international and national targets for greenhouse emissions, and the schedule for their attainment. One of the more difficult issues is the recognition that developing countries will be unable to meet the same levels of emission controls as the industrialized world, and will therefore need both financial and technological assistance. Another is the equivalency among greenhouse gases. Third, nations must decide what measures to take to meet emissions targets. Global measures, or harmonization of measures may be negotiated, but given cultural and other societal differences among them, countries are more likely to choose to implement domestic policy instruments.

Formal negotiations on a framework convention on climate change commence this fall. The federal government, drawing on recommendations from federal and provincial energy and environment ministers, is developing Canada's position. It is hoped by many nations, including Canada, that the convention will be signed at the upcoming UN Conference on Environment and Development in 1992.

Failing an international agreement on global warming, Canada is faced with the decision of whether to act alone to reduce greenhouse gas emissions. Canada is responsible for only a small portion of global emissions of greenhouse gases. Any unilateral measures it takes would therefore not have a significant impact on global warming. At the same time, the measures could negatively affect Canada's competitive position in increasingly global markets, unless other countries take similar unilateral measures.

While meeting the challenge of global warming seems formidable, there is reason for some optimism. Canada and other nations have already taken some co-ordinated and unilateral action to control the emissions of greenhouse gases in response to other environmental problems. Internationally, chloroflourocarbon or CFC emissions are already being reduced under the Montreal protocol to protect the ozone layer – the first global air pollution control program. In addition, Canada has taken unilateral action to phase out controlled CFCs by the year 1999. Canada is also a signatory to an international protocol to freeze nitrous oxide emissions (NO_x) at their 1987 levels. In response to this protocol, as well as in response to concerns about local air quality, a plan is being developed to further manage NO_x emissions in Canada. Concerns about air quality have also led to an agreement between the federal and provincial environment ministers to introduce, within five years, stringent regulations to control emissions from internal combustion engines and their fuels.

The federal government will ensure, through measures that will be introduced in the Environmental Agenda, that Canada continues to take a lead internationally. It will also ensure that we continue our efforts to deal with more local and regional environmental problems which at the same time reduce emissions of greenhouse gases - many other nations are doing the same. Actions and initiatives could include, for example, more efficient

energy use, product substitution, use of alternative fuels and non-polluting processes, improvements in modes of transportation, and public education to encourage individuals to do their part.

Implications for Canada

In developing Canada's position in the upcoming negotiations on an international framework convention on global warming and the implementing protocols, we clearly will need to examine the socio-economic implications for Canada. Given the structure of our economy, the implications could be very significant.

Roughly half the annual world emissions of greenhouse gases come from the combustion of fossil fuels. These emissions are projected to rise substantially over the next century in the absence of an agreement to limit their growth. Canada, with its cold climate and large distances, is one of the most energy-intensive economies. About 80% of the energy we consume is generated from the combustion of fossil fuels.

The single largest source of greenhouse gas emissions produced by the combustion of fossil fuels is carbon dioxide. Canadians, while accounting for only about 2% of energy-related carbon dioxide emissions, are the fourth largest producers of carbon dioxide on a per capita basis.

The transportation and the industrial sectors are the major contributors to carbon dioxide emissions in Canada – each accounts for about 25% of the emissions. The generation of electricity from coal is another major source, accounting for about 20% of CO_2 emissions. It is these sectors that therefore provide the greatest scope for reducing carbon dioxide emissions.

There have been proposals from numerous sources, including the World Conference on the Changing Atmosphere which was held here in Toronto in 1988, to reduce worldwide emissions by 20%. The federal and provincial energy ministers have been examining the implications of reducing CO_2 emissions by 20% of 1988 levels by the year 2005 as recommended at the Toronto conference. They have also been examining the implications of stabilizing CO_2 emissions at 1988 levels within the same time frame.

The energy ministers have projected that emissions of carbon dioxide in Canada could be about 50% greater in 2005 than in 1988 to meet the energy demands of economic growth and a growing population. On the basis of this projection, they have concluded that achieving stabilization at 1988 levels, and in particular reducing emissions by 20%, would require fundamental changes in the way Canadians view and use energy. Significant economic costs would be imposed on Canadians, and they would be required to make dramatic changes to their way of life. A key question facing Canada, and one the federal government is seeking an answer to in our upcoming consultations, is to what extent these costs are acceptable to Canadians.

Global warming clearly cannot be addressed without raising very difficult questions about the way we produce and consume energy. No energy source is without environmental impact. While the burning of fossil fuels is linked to global warming, coal, which is burned in industrial plants and in the generation of electricity, also releases sulphur dioxide which contributes to acid rain. Alternatives for electrical energy generation – hydro and nuclear – also have environmental impacts. The generation of hydro-electric power requires the construction of power dams and transmission lines which have a negative visual and ecological impact. Nuclear, while having the advantage of not emitting greenhouse gases, raises questions regarding accidents in operating nuclear plants and the safe disposal of nuclear fuel waste.

Canadians face some very hard choices. It is important that they have objective information on the advantages and disadvantages of different energy forms, and an appreciation of the difficult trade-offs involved. Late last year, the Minister of Energy and the Minister of the Environment, in announcing the terms of reference of the environmental assessment of a concept of deep geological disposal of nuclear fuel wastes, agreed to set up a public discussion of the role of nuclear in the context of the advantages and disadvantages of different sources of energy.

Implications for the Transportation Sector

The transportation sector faces perhaps the biggest challenge. It currently relies almost entirely on the combustion of fossil fuels, the relatively easy gains in fuel efficiency have been made, and non-fossil alternate fuels are so far not attractive.

Energy conservation is clearly a first step in reducing carbon dioxide and other greenhouse gas emissions. In fact, the transportation sector has made significant progress in efficiency improvements in response to rapidly rising oil prices in the 1970s and 1980s – the efficiency of motor vehicles has improved by about 22% over the last decade. Federal and provincial energy ministers are currently considering actions to further encourage energy efficiency and conservation.

Emission standards is another means of reducing greenhouse gas emissions. As I noted earlier, federal and provincial environment ministers agreed to introduce, within five years, stringent regulations to control emissions from internal combustion engines and their fuels. These will further reduce nitrous oxide emissions, giving overall efficiency of about 90%.

Further improvements in fuel efficiency and tighter emission standards impose significant technological challenges for the transportation sector. But they will not be enough to stabilize greenhouse gas emissions. There is lots of talk about the introduction of economic instruments, for example a carbon tax, to reduce the demand for fossil fuels. A number of studies have examined how effective a carbon tax might be in stabilizing CO_2 emissions. They all conclude that a very large tax would be required to induce changes in behaviour. A tax of the magnitude required would result in a major structural change in our economy, and would have major distributional effects.

It appears that the greatest scope for reducing greenhouse gas emissions from the transportation sector lies in the development of convenient and economic alternate fuels.

Conclusions

Canadians face the challenge of both meeting future energy needs and minimizing the environmental impacts associated with the production and use of energy. The problem of global warming is a big part of this challenge.

We have made some inroads. We have become more efficient in our use of energy, and efforts are continuing to make us more efficient. We have taken measures, in co-operation with other countries and unilaterally, which will reduce greenhouse gas emissions. And very stringent emission standards for internal combustion engines are being introduced.

From here it will get increasingly harder. The most difficult part is the prospect of giving up some of the amenities that energy provides, and the drastic changes to our life-styles that would likely entail.

Canada's participation in dealing with global warming will indeed be a big challenge, and one which is a major environmental policy issue for the federal government. A big question is how far Canadians are willing to go. It will be important in the federal government's upcoming consultations process for Canadians to express their views on how the challenge of global warming can be met, and on what trade-offs they are willing to accept.

TRANSPORTATION TECHNOLOGY - MAKING IT HAPPEN
PANEL DISCUSSION

Moderator - Norm Mealing,

Executive Director, Provincial Transportation Division
Ministry of Transportation

Although I was acknowledged last night to have had a hand in this particular program over yesterday evening and today, I'd be remiss if I didn't acknowledge right now the efforts of people like Mike Ernesaks, Junette Douglin, and Irene Rapa. I know that Milt will say a little bit more later on, but as I say, I would be remiss if I didn't acknowledge their efforts. They've done a super job.

I'd also like to point out that although your program says that David Crane will be with us, he has cancelled. He is interviewing, as I understand it, the President of Mexico.

This morning our keynote speaker told us that we have to become more innovative, that innovation is the end product, and that research and development is the means of getting there. Also it was pointed out that we must become more end-user oriented, otherwise our innovation is for nought. It was further suggested that innovation and research and development must involve a team made up of the user, industry, academia, and government, and that all must work in concert with each other. We also heard about some new and emerging technologies that could be used to solve some of the transportation challenges of the 90s: things like smart cars and the intelligent highway, automated transit ways and guide ways, and automatic vehicle locating and control systems.

We have been told over today's sessions that technology is playing a leading role in international competitive performance and that R&D, involving new and emerging technologies, is the key strategy which could ensure that Canadians maintain the quality of life they are used to as well as success in the marketplace.

In a recent address to the Empire Club, Geraldine Kenney-Wallace, chair of the Science Council of Canada, described research and development as equity investment. She went on to say that in Japan and in many other rapidly growing, highly industrialized countries of the pacific rim, where there are no abundant resources to harvest or mine, they had to look for equity and collateral elsewhere.

We've also heard that Canada is lagging behind in research and development and the adoption of state-of-the-art technology. The basic question relating to research and development in transportation technology is how *we* can make it happen. And to help us answer that question and find solutions, we have invited a group of talented and experienced and knowledgeable professionals to be with you this afternoon.

Specifically, we've asked the panel to address the following points: the need for long-term strategic thinking, planning, commitment, and funding for R&D. What needs to be done to create the right environment for research and development with a focus not only on what is necessary to make it happen, but also some discussion of some of the major pitfalls. How to achieve the necessary co-operation between the end-user, academia, industry, operators, and government. The government's role is a catalyst. What other roles do the government have. And what are the relative roles of the provincial and federal governments in the exercise.

I would like now to move to introduce our panel members and I will introduce all of the panel members before we begin. To my immediate left is Len Pitura, who is Deputy Minister of the Ontario Ministry of Industry, Trade and Technology. Len was appointed to that position in September of 1989. Prior to this appointment, Mr. Pitura served as Executive Vice-President of the Liquor Control Board of Ontario, a position he held since 1987. He began his Ontario Civil Service career with the Ontario Water Resources Commission in 1963 and moved to the Ministry of the Environment in 1974. He has attended the National Defence College and in 1978, he was appointed Director of the Ministry of Environment's Waste Management Branch. From 1980 to '82 he was Director of Organization and Management Policy for Management Board of Cabinet, following

which he was appointed an Assistant Deputy Minister with the Ministry of Housing. Len is a graduate of the University of Toronto and I was told, Len, when I introduced you, that we in the ministry don't hold that against you even though the majority of our engineers are Queen's graduates and he is a member of the Association of Professional Engineers of Ontario.

Seated next to Len is Bob Mayes. Bob Mayes has an extensive background in the field of transportation and since 1983, he has served as the Director of Research and Development for Transport Canada, where he is responsible for the management of the Central Technological Research and Development Program of the department. He joined Transport Canada in 1981 as Director General Energy Planning where he was responsible for monitoring and ensuring the effective analysis of energy supply and demand trends and their likely impact on transportation in Canada. From 1974 to 1981 he was employed by the Canadian Trucking Association and he has also served as Executive Secretary on the Standards Council and Chairman of the Transport Canada Highway Research and Development Advisory Board. He received his Bachelor of Science degree in Civil Engineering from University College, London University England, and has a Master's of Applied Science and Management Science from the University of Waterloo.

Seated next to Bob is Don Sheardown. In addition to being the sponsor of the NHL Oldtimers, Don is an occasional player with the Oldtimers, as I understand it. He is the President of the Ontario Bus Industries Incorporated and one of the best examples of successful entrepreneurship in Canada. Most of his career has revolved around building up largely successful companies in the transportation field. The real success story, however, is the purchase of OBI in 1980 and the turning of OBI in Mississauga and its U.S. subsidiary, Bus Industries of America Incorporated in Utica, into the company which produces 700 buses a year, employs 850 people, has 24% of the bus market in North America and some 3000 Orion buses in transit service.

Very recently, OBI was awarded major bus contracts in Pittsburgh, Milwaukee, and Madison, Wisconsin, bringing the total orders for the company to over a 1000 buses to the value of some $250 million.

Don has met the U.S. competition head on and is now taking on the Europeans and recently sold a fleet Orions and standard buses to Sweden. Don has taken a long-term view to business and is a strong advocate of R&D. As a result, his products are innovative, state-of-the-art, and designed with the end-user in mind. Examples include the internationally acclaimed Orion II bus for transportation of the disabled, for which he received the Outstanding Business Achievement award in 1984 and the Canadian Award for Excellence in 1985. Currently, Don is engaged with our ministry in research and development of alternative fuels, focusing on the successful application of natural gas to buses. He is a Director of the American Public Transit Association and a governor of the associate members in APTA.

And finally, next to Don, we have Dr. Anthony Eastham. Tony Eastham is a Professor of electrical engineering at Queen's University in Kingston, having joined the faculty in 1978. His research activities include innovation, urban and high-speed transportation, linear and rotary electric drive, and electro-magnetic analyses. As administratively, he currently serves as Director of Research Services and of International Programs at Queen's University. Before moving to Canada in 1972, Tony held research positions at Plessy Telecommunications Ltd. and the University of Warwick. When he arrived here, he joined the Canadian Institute of Guided Ground Transport, where he coordinated a team that researched, defined, and assessed the Canadian maglev system for high-speed ground transportation. He is a registered professional engineer in the Province of Ontario, senior member of the Institute of Electrical and Electronic Engineering, and a Director of I.E.E. Canada, and President of the High-speed Rail Association.

That is your panel, ladies and gentlemen. I've mentioned to each speaker that we're looking for about ten minutes by way of remarks, after which we will have a general discussion among the panelists. First off, I'll turn it over to Len Pitura.

Len Pitura

Deputy Minister, Ontario Ministry of Industry, Trade and Technology

Firstly, let me admit, very much I'm not an expert in transportation, so you can throw that concern out the window. In case some of my friends in the audience think I've suddenly become an expert in six months, I haven't.

Certainly, as Deputy Minister for Industry, Trade and Technology, I'll say that research and development is very important. It's one of our mandates, and so certainly, when I was invited by Pat Jacobsen and others to participate, I grabbed the opportunity. It gives me another forum in which to speak about some of the things we're trying to do, both in the province and of course dealing with our federal cousins.

No doubt, and I'm sorry I missed most of the proceedings, but the importance of research and development to this country, to this province, some say that research and development may be today's advanced educational model. The model that is going to determine whether we as a province, we as a nation, are going to be competitive in the global marketplace. And I'm sure speakers before me have announced that time and time again. But I think it is important to keep underlining that.

The other thing is, unfortunately Mr. Chairman, probably the people that are in this room are the ones that are already educated and aware of the importance of the need of investment in R&D. It's the people who drive by this hotel today, that perhaps have to be informed. The public awareness campaign. But in any case, I think that's the challenge we all face if we are going to get political support for more investment, if we are going to get industry support for more investment in research and development.

As far as Investment Canada, you've all heard the figures, I'll repeat them again, because it just underlines where we are, if we are to compete and not fall behind. We have something like 1.28% of our GDP going into research and technology in 1989. Now this is down from 1.4% in 1985. So we're going in the wrong direction. Canada currently ranks 10th in R&D intensity among the 12 largest OECD economies. We're behind the United States, Japan, Sweden, Germany, France, U.K., Switzerland, Netherlands and Italy. But we are ahead of Australia and Spain. I don't intend to offend anybody from those two countries, but we're near the bottom of the pack.

And one aspect of that, that doesn't tell the story, is the amount of investment in R&D by industry. Governments at both levels, three levels perhaps, perhaps put more into R&D than industry has in the past. That's one of the messages we're bringing to all the various industrial sectors in the province is more emphasis on research and development. So, I guess just a quick question that we have to ask ourselves as Canadians, do we have the capacity to succeed, and do we have the will to succeed, are we ready to show leadership where we can play a leadership role?

And as mentioned, we as a province have tried to convince our other sister provinces and the federal government of the need to set a target for R&D. A goal of 2.5% and that was agreed to back in September 1988. Unfortunately, I can report to you as recently as of Monday of this week when we had a meeting of officials, we have gone farther back. There is no acceptance, I think, at the federal level and I'm not trying to pick on poor Bob here, it's not his responsibility. But what I am trying to point out is that we as a country can't seem to get our act together on R&D. We're going to have another meeting of the provincial ministers and the federal minister in Sudbury in April and again we're going emphasize the need for a national commitment to research and development.

As far as co-operation, this thing can't be done by government alone, or by industry alone. As has already been mentioned, there is a need for partnership among government, industries, and universities. We have to create the right environment for R&D to flourish. We have some outdated attitudes. Some of the university crowd would not like to be involved with industry and

some of the industry would not like to be involved with university. One of these little crosses you had to bear, I like to think that's breaking down, but certainly that's an area that has to break down, if we're to work together and progress together.

So, we have to get rid of some of those old attitudes. We should be looking to see how we can strengthen the infrastructure that encourages innovation and development. We should be looking to see where we can co-operate in research, both basic and applied. We should be looking at how we can change our approach to education and training in order to produce a more competitive workforce.

And lastly, I know Bill Weinstein would like me to say this: how we can increase the number of scientists and engineers and, equally important, the numbers of science-oriented entrepreneurs graduating from these schools. And again I'm just saying what speakers I'm sure have said earlier in conferences in the last two years who have stressed the same thing, but again we have to keep repeating it. As far as the transportation sector, it's obvious how this country came together. Most countries came together because of revolutions, some bloodletting in one form or other. This country has come together by transportation, rail, communications, of course we know what's happened to VIA in the last few months so maybe we're coming apart in spite of Meech Lake. But certainly transportation has been a vital part of our economy. And I think a lot of it has been developed through the joint co-operation between government and industry. I'm sure this is going to have to continue in the future and such things as automated road analyzers, you've heard of smart cars, maybe we're going to have some smart drivers to handle all this. People or companies like OBI here who've shown themselves as leaders in the transportation field.

I'll just diverge for a second, I was in Chicago a month or so ago. I hadn't really heard much about OBI till I was in Chicago and met the chairman of the Chicago Transit Authority, who I swore worked for OBI. She was so supportive and appreciative of all the efforts of this company in Ontario has done to make her life that much easier. So I'm putting a plug in for you, Don, in case you are going to have to say something nasty about me.

We are in part sponsoring what I call a very high-tech project, it's involving the monitoring of vehicles via satellite and it's being funded by the Premier's Council on Technology, our Techfund. There is a consortium which will include Telesat Mobile, Frederic Transport, and Thompson Transport. So that will give you one example of where we are trying to invest in the development stage to help Ontario's transportation.

Airports, marine transport, seaway technologies and, of course, the development of alternative transportation fuels. Sustainable development, I gather you had a session on environment earlier, and I won't go into that. But certainly the elimination of toxic emissions and the impact of transportation on the environment are clearly issues we have to address while we're looking at R&D. We have to, again just to summarize, make sure that partnerships of government, industry and universities are made and are practised.

As far as public awareness, I've already mentioned the need, not for people in this room, because you're here because you know a lot about this business you want presumably to learn a bit more, but it's the people on the street, the constituents, the elected officials, who have to hear more as to why investment in research and development, whether it's in transportation or some other sector, is essential if this country is to progress. And that, I think, Mr. Chairman, is the challenge that I'd like to throw out to the audience is, how do you do that?

Some other initiatives. As I told you, we have the Premier's Council on Technology. It issued a report in 1988 entitled "Competing in a Global Economy." Great emphasis on research and development. As a result of that, there's been roughly one billion dollars set aside that we're investing in centres of excellence, university research, etc. in order to make up some of the gap in research and development in this country and in this province.

And right now that Council is looking at the human resources aspect, looking at the training needs of this province, looking at the educational needs of this province, and perhaps more in harmony with what's happening around our province today, looking at labour

adjustment practices in this province with some industries restructuring and getting ready to compete and to survive. And we hope there will be a report, later this year it'll come out, that will give you some indication of where this province is going in education, training, and adjustment as it applies to our position in the global economy. We're involved with lots of universities, something like seven of them, a hundred companies, they're are all tied in with the research fund. As far as universities, we've got about $50 million tied in with various universities in this province, and again it's on a 50/50 with universities providing 50 cents in a dollar, industry provides the other 50 cents.

We have a tax incentive plan to support research and development and that's going to cost something in the order of $300 million in the first five years. We've created a technology personnel program which will encourage small and medium-size companies who do not have the where-with-all to hire and recruit scientists and engineers in their development work. We've come up with this program, it's not an earth-shattering one, but it's an attempt to get companies to hire the technocrats in order to help them develop a better product, be able to compete better.

And we're also trying to work with what we call our indigenous multi-national companies. These are the companies we think that have the where-with-all to make it into the international marketplace. Certainly we could do a lot more in that area, but those are just some of the examples, Mr. Chairman, of some of the things we are doing as a province. I could probably spend another five, ten minutes, but I know you've only allocated me ten, even though I've got a 20-minute speech. I'll be prepared to answer all sorts of questions later on. Thank you very much.

Bob Mayes

Director General, Research and Development, Transport Canada.

The remarks that I'd like to give you this afternoon are from the perspective of someone who manages a research program in the federal public service. And as Norm said, we were asked to talk around five points, so I've organized my comments around that. I hope that to some degree you'll agree with me. To some extent you may want to disagree and we can pick that up in the question period.

So starting with the first point. The need for long-term strategic thinking, planning, commitment, and funding. Transportation is an applied field. It's not primarily *curiosity*-driven, in my view. Rather, it's problem-driven. Having said that, there is still a need for creative thinking and any innovation or even invention that comes along will ultimately end up changing a status quo that requires delivering transportation services in real time. So therefore, I believe in order to be successful at all, if we are engaging in the business of transportation technology development, we need a strategic approach. We need to gain support for the innovation which may include invention that we are embarking upon.

To use a specific example, the way we go about our business in Transport Canada. From time to time we undertake strategic technology assessments in order to try to build a consensus on where emerging technologies are coming from. For example, about five or six years ago we did that with the field of expert systems, we've done it done more recently with the field of advanced materials in transportation, the application of advanced microelectronics. We even did a study just two years ago on likely impacts of climate change in transportation, the idea being to try to poll the people who are likely to be involved in any change that comes along, so they're sensitized to the issue.

Once we've completed these assessments, we then build on them on an annual basis to what we call strategic planning guidelines, which attempt to force together if you will, the technological opportunities that may be coming with the overall priorities in operations of our department. These guidelines then allow projects to be defined in several multi-year programs. So summing this up, it's a fairly complicated process, but I would argue that it has to be. I think coherent transportation research is not just a collection of isolated projects, it's a coherent and planned activity and it does require a multi-year commitment. I also firmly believe it should be client-driven. I believe that we should be, in transportation, in a demand pull rather than in a technology push mode. I know there are certain people here who will disagree with me. I hope that you will.

The second topic we were asked to address was: how do you go about creating the right environment for R&D; how can you help this technology development to happen; what pitfalls are there?

I think to begin with, I'd like to address two aspects of the environmental issue, in the sense of the organizational environment issue. First is internal, the second external. Internally, there is no question in my mind that we *must* maintain whatever expertise we have in a continuous way. You can't turn on and turn off the knowledge-base with respect to people. We heard this morning, for example, a couple of presentations on advanced technologies for highways, the IVHS projects. We also heard that there are human factor issues associated with this. To the best of my knowledge, we do not have a corpus of knowledgeable professionals who can assist us in wrestling with this very complicated problem. So, maintaining and enhancing continuity of expertise is very important.

Somewhat associated with that, I think if you're in the R&D game in technology in general you have to maintain a flat system. You've got to take hierarchy out of these groups. It's very difficult to do in government I might say, it should presumably, hopefully, be easier in industry. But try to eliminate hierarchy, try to think in terms of *networks* of people working together, with specific nodes interrelating in parts of the organization. It's very, very helpful, very essential.

And then another thing that has to go on by research managers in the organization is all the development of support for and maintenance of support for any R&D program. This goes back to the first point that we were asked to cover: a great need for strategic thinking and for strategic planning.

In terms of the external environment within which an organization is working, I think it's important that there be a stable regime, fiscal tax regime. Changes in things like R&D tax credits, for example, create confusion in terms of potential investors in the private sector in R&D. It can be very harmful. We've seen that. If you are to have R&D support programs provided by government, again they need to be stable, they need to be well understood. You shouldn't be changing your priorities on an annual or even bi-annual basis.

And again, going back to the point about strategic planning and strategic thinking, I think the provision of technology assessments from time to time is very important in terms of developing a common understanding between government or governments and the private sector on what technological opportunities in the sector might be.

So what do you need to make it happen? I think you need to identify and stick with a set of research priorities. You need to build and maintain a consensus, that's inside and outside of government. You also need to recognize, I believe, and I believe this very firmly, that you're working in a top-down and bottom-up mode. What I mean by that is, you use your managerial and executive expertise to define your priorities, the problems that are critical that you solve. But you recognize in the bottom-up mode that the solution of that problem comes from technological and technical expertise. And this brings us into one of the major pitfalls. There is impatience and frustration with this ragged-edged process, which is a mixture of top-down and bottom-up. And I think that's a major problem for those of us engaged in technological development in the public sector.

Also I think uprooting a program every 12 to 18 months to see if it's growing is a pitfall. It's one that we find quite often in the public sector. Sure, you need evaluations, no question about that. If you're spending taxpayers' money, you need to evaluate a program. But I think a frequency of 12 to 18 months is a little too frequent.

There is a problem with critical mass, I think. Not just federally but also provincially and also in industry. We heard the figures quoted about our national commitment to science and technology. And that really devolves back to the number of people involved in given fields. We're down, we know as we look across the country, to single points of expertise in certain fields. If that person walks away, our expertise evaporates with the person walking away. We're getting spread far too thin.

The lack of funding itself is an issue. I know we have theological problems in Ottawa with respect to this ratio of R&D expenditures to the Gross Domestic Product. The figure earlier was mentioned about 1.28%. It's even worse in transportation. In transportation we're 0.7% of our contribution to the Gross Domestic Product in terms of R&D expenditures. And in fact two thirds of that is in the aerospace/aeronautical sector, which means all the rest of it is about .2%. So it's a major problem: continuity of funding and the availability of funding.

And then a final pitfall in terms of the development of transportation technology, I think, is failing to modify our priorities as conditions change. Now, we heard several people this morning recognize or bring to our attention, if we were not aware of it already, that we are in the middle of an aging society and that the needs of older drivers will be different from the younger drivers that we've had for the past 25 years. We're also now very aware of the need to have a more environmentally benign transportation system and so on. So there is a need, over time, to refine these research priorities.

The third point we were asked to address was that of how can you concert co-operation between universities, industries, and operators and government. Our speaker last night emphasized the need to enhance teamwork. Dick John mentioned it again this morning. This co-operation, though, implies that we've developed a consensus, we have a common understanding of what we need to do. I maintain that the problem is what that you use *internally* within an organization, to gain support

for your developmental program, has to be extended much broader than the organization, clearly. And this is not easy to do. There are different interests in the academic world and industry from those in government. And finding common elements is a time-consuming and difficult process, especially when we're in an environment in which marketplace considerations are taking more prominence than previously.

There have been attempts to enhance this co-operation recently. A number of us were very disappointed that the transportation network of excellence was not selected for funding last fall. It got excellent reviews but funding didn't come through. However, it's not all dark. There are points of light, as we've heard. We've had success stories in the recent past in Canada with respect to co-operation in technology in transportation that MTO has been involved in. Think of the RTAC vehicle weights and dimensions program, for example, which was successfully completed a couple of years ago. Or the current Strategic Highway Research Program that is currently building on the U.S. counterpart program. In Ontario there is the Canada Coach Lines demo in Southwestern Ontario, where there's a great degree of co-operation between manufacturers, operators, and two levels of government.

So, co-operation *does* exist. It's difficult to foster. We need to build on it, I believe. And we need to build on the successes very soon.

We've heard several times about competition off-shore. Japan has been cited in particular several times and I think it's worth citing a few elements of the Japanese mode of doing business. First of all, they spend a lot of time and effort developing their consensus. It's a cultural norm for them, spending time between the academic world, industry, and government to get a common consensus. Not that government pays for everything, that's a misconception. Of the R&D expenditures in Japan, 80% of them are undertaken by industry, only 20% by government. But there is a lot of time and effort put into the consensus development mode.

The other aspect of Japan that I think is noteworthy for us is that at the pre-competitive stage they co-operate with one another. However, *post* the pre-competitive stage, they compete furiously with one another. Again these are cultural norms that they are happy with. And then, again, in terms of their *level* of effort, 3% of their GDP is currently allocated towards the development of science and technology. That is targetted to be raised to 4% by the year 2000, with the incremental 1% (from 3% to 4%) being in the fundamental sciences.

Now if you forget all that I've said about Japan so far, just remember one thing: that last year, the Toshiba Corporation, which is not the largest R&D performer in Japan in the private sector but probably third or fourth, spent more on R&D than the whole Canadian private sector combined. So we have some formidable competition.

Competition to the east is also noteworthy and growing. As the European Economic Community becomes more of an economic entity, their R&D programs are growing too. We've heard this morning about Prometheus and Drive and Eureka and so on. And these again are incremental to national programs. They're not in place of, but they're incremental to. So, I think all of this asks the question: if we don't co-operate together, what chance is there for us?

The fourth point we were asked to address was government's role as a catalyst. I think the simple answer is yes. There is a role for government to accept the higher risk element of R&D projects, to do the sort of work that's far too risky for individual firms. This is recognized both in the national science and technology policy, federal policy, and also in our departmental R&D policy. What does it mean? How is it done? It means that you should fund some of the riskier and the conceptual development stage of things. You should do technology assessments, broadcast that, try to help develop a consensus with industry.

And then the last point we were asked to talk to: the relative roles of provincial and federal governments. In transportation I think we have to recognize that R&D and technology development is related to capital and operating budgets. So it makes some sense that the federal government concentrate on the things that it has

got either an operating or legislative responsibility for. And the same probably goes for the provinces too.

Nevertheless, from time to time, it's possible to articulate national needs. I use the example of the vehicle weights and dimensions program or the C-SHARP Program. And then, when you've successfully done that, it is possible to enter into agreements, federally, provincially, with industry, in order to launch a program of some size. At the moment, for example, there is some incubation, if you want, going on as to whether there should be a Canadian equivalent to the IVHS program, that's been spoken about in the U.S. I don't know what the outcome will be, whether there is a role or not, but certainly people are addressing that issue.

I think also as we talk about governmental roles and responsibilities, we don't need to be too slavish about it. Technologies will find a niche wherever it's appropriate for them to do so. I'll give you an example. We worked with a company in B.C. to do some voice synthesis technology to get transit schedules information to the customers. That has been migrated to the airport weather information system. So if there is an appropriate niche, I think that the technology will find it. It tends to transcend jurisdictional niceties.

Finally, there has been a recognition of the need to improve the process that we use to allow effective research programs to be undertaken. Most of you, I'm sure, are aware, at the macro level in Ottawa there's now a new department of Industry Science and Technology that puts together the interests of industrial competitiveness with the science and technology base. At the micro level, if you want, within Transport Canada, we've also reached out over the last few years to get better linkages with other agencies. We have an MOU, Memorandum of Understanding, with MTO. We've had a co-operative research program with Quebec for the last five years. We have a formal agreement with the National Research Council, the idea being to spend time matching priorities so that, if possible, we can develop research projects of mutual interest. So the point Dick John made this morning about the process being almost as important as the product, at least that's my paraphrase of what he was saying, I think is very important. Anyway that's it for the time being.

Don Sheardown

President, Ontario Bus Industries Incorporated

To begin, I would like to acknowledge a person. I would be remiss if I didn't. There is a person here that is our vice-president of engineering. The guy that is a creative person, the guy that's got the brains of this company. And the guy that I lean on heavily, Peter Bigwood, our vice-president. I'd like him to stand for the people who don't know him. I'd like them to recognize him.

Before I start, I'd like to thank, because in here there are a few things that I'm going to say about the ministries, but without the provincial transport ministry and the Ministry of Industry, Trade and Technology, our company would not be here today and there is just no doubt about it. Over the past ten years, I've leaned heavily on those two ministries. And on the darkest days those doors opened. So I appreciate them.

I'll try to give you a background on our company. Len said he didn't know about our company. I'll try and summarize it in 10 minutes so you do know it, and then when you're in Chicago or Milwaukee or New York you can sell some buses for us.

I'll say something about our achievement, our challenges, and our future developments. Ontario Bus is an offshoot of Ontario Bus and Truck Repair. And it was founded in 1975 by Arnold Wollschlaeger. The first product was developed. Arnold thought there was a need and a market for a 30-foot heavy-duty transit vehicle and he undertook to develop that product. The total development cost was born by Ontario Bus, which when completed, totally drained all his capital from both his companies. He then asked the provincial government for assistance and that was refused because the prototype was already built and the governments are not there once the prototype is built, it should go into manufacturing. He went to the banks and the banks said there is no future in this bus, so we can't give you any money. So he was forced, in order to survive, he sold the rights for the Orion I to GreyHound Corporation and for the world excluding Canada. And unfortunately at that time for Canada that was a great loss. After the sale to GreyHound, the company still faced a major financial crisis and the provincial government at that time then approved the sale to Ottawa of 30 Orion I 30-foot buses, which are still in operation today. They probably have about 800,000 miles on them, they are 11 or 12 years old.

At the same time the Ontario government, through the Ministry of Industry and the Ontario Development Corporation, provided a $500,000 loan guarantee, which then enabled the company at that time to continue operations. Due to the death in early 1979 of Mr. Wollschlaeger, the family was forced to sell the company, and I was fortunate enough to be in the right place at the time and purchase the company. And the deal closed 10 years ago last week.

The government immediately withdrew their loan of $500,000 and that was a clear signal to me what the provincial government thought of me at that time. In 1980, after GreyHound had produced 750 buses, we purchased from GreyHound the world rights, which enabled us to enter the U.S. market and open up our subsidiary company, Bus Industries of America which is located in Utica, New York.

In 1982, we were approached by the federal government through the Ministry of Industry with grant money to develop a low-floor bus, which would be accessible for the disabled, which would feature a frontwheel drive and we called it the Orion II. This project, which had an original development cost of $1.8 million, of which we were to put $400,000 in and the federal government $1.4 million, grew to a final cost of $5.5 million, because we had a commitment and we stayed on with the commitment. And I think in R&D that is what you have to do. Our share was 60% and the federal Government ended up 40%. And I might add this project has been the most gratifying for our company, the most problematic, the most educational, and the project which was instrumental in building a development team at OBI, which has enabled us to develop many products since.

This was my first experience of dealing with government and I now have a better understanding of the favourite line. "I'm from the government and I'm here to help."

In 1985 we participated in the development of the National Research Council's Regeneration Bus, which has not yet reached commercial application. This development has many advantages, both in fuel economy and emissions. Our CNG bus development was initiated over four years ago with the assistance of the gas industry and the Ministry of Energy. In parallel, the Ministry of Transportation has over the years funded development in the engine field and as a result we are participating in the most important and advanced CNG demonstration program in North America. And we got a confirmation letter today the Ministry here in Ontario, with the purchase of 50 CNG buses, certainly has raised our profile in the United States and in Europe. Today we got confirmation of the first buses we have sold, CNG buses, from Tacoma, Washington and we've sold 15 there and confirmed that order. And I would remind our friends from California that we have many more slots open on our production line if they would like some CNG buses.

We can say that thanks to the co-operative program with the local transit operators, local gas companies, and the Ontario government, particularly the Ministry of Transportation here, we are the world leaders in the field of CNG-powered transit vehicles.

Our next project, "People Mover," which probably many of you have seen in Niagara Falls, we started in 1985. We financed that project entirely and, in spite of many very unusual new features, including propane power, it has been a most successful project and certainly again raised the profile of our company and our abilities to develop and manufacture.

The Orion Ikarus articulated bus and again in 1985 we made an agreement with Ikarus that we would bring the frames of the articulated buses from Hungary. The reason for that was because of their small market and we felt that there was a need for an articulated bus and certainly a market. So we have produced 254 of those buses for Ottawa and Toronto, I'm sure which you've seen on the streets. Our new Orion Five the 102" 40-foot bus is an evolution of our original Orion I bus, which we developed and started manufacturing at a total cost of less than $1 million including tooling. And we compete, and you'll find this very interesting, that GM developed the RTS and subsequent to that they've sold the company to GreyHound MCI where they're being manufactured in Roswell, New Mexico. Their total cost to purchase and set up that busline is $270 million, so we are competing directly against them in the United States and we meet all the specifications with our bus and it cost us a million and they got $270 million in theirs.

In summary, I've given you an example of five of our major projects, some of which we have accomplished with government assistance and some of which we have accomplished on our own. Our experience has proven that as long as government agencies have the right people in place who understand the problems the private sector faces, in particular financial, which can change course throughout the duration of the long-term development, joint ventures can be successful. However, along with these partnerships must come great flexibility, so that the private companies who are willing to risk their capital can be successful, which in return creates employment and exports from Canada.

I would suggest that the government entertain the possibility of loaning their most talented people to industry on a long-term basis to assist in venture projects. It would then be involved because when we're on development projects, we're sometimes dealing with four different ministries. The mentality of ministries vary dramatically in their thought process. Some make decisions and others find a way not to make decisions. I find it very difficult to try to work with four ministries. We've had great co-operation on this CNG project from the Ministry of Transportation. But other ministries are very difficult to work with. So if there was one ministry that could focus and bring these people and have the answers, it would be very helpful. It's important to a company such as ours because the CNG project stood a good chance of not happening for the simple reason, it takes too long to get decisions. We make decisions and we make them happen. But the ministries have to make it happen too.

I believe that Canadian manufacturers need the help and support and understanding of both the federal and provincial governments. Where possible, promote the purchase of these products within their local jurisdictions. As far as future projects are concerned, we are in the initial stages of developing a hybrid electric drive vehicle, with the combination of a small engine and battery power. This new technology could lead to a low-floor bus with the possibility of three double doors, one being behind the rear axle. There would be a 33% fuel-economy improvement by using natural gas, power regeneration, and by operating the engine in a better power range at a constant speed. We could set a goal of one tenth the current emissions of diesel engines. We plan to have this project vehicle ready for testing in the next three years. And, yes, we will require government grants on this project.

In closing, I would like to thank Minister Wrye, Gerry Johnston, Norm Mealing, Milt Harmelink, Ovi Colavincenzo, Mike Ernasaks, and their staff, the ministry and staff that best personifies to us what government agencies should be to the private sector. And when I knock on your door and say "I'm from Ontario Bus, we need grant money," trust me.

Antony Eastham

Director of Research Services and Professor of Electrical Engineering, Queen's University.

Transportation Technology -- Making It Happen. I guess I'm going to offer some thoughts really from two perspectives. First of all, from the perspective of one particular technology that I've been involved in for some twenty years now, and secondly from the perspective of transportation research engineers and academia in the province of Ontario.

First of all, as Norm said, one of the hats that I wear is that of President of the High-Speed Rail Association, an international organization dedicated to the implementation of high-speed rail systems in various corridors around the world. And I'd like to address the topic of this panel by offering some thoughts about generic high-speed rail systems and I regard those as both advanced steel-wheel on rail technology and also the non-contact magnetic suspension technologies, particularly in relationship to the Toronto-Ottawa-Montreal corridor.

I came down to Toronto from Kingston yesterday for a meeting prior to this conference associated with Engineering Week, and I found it necessary to drive here, as there wasn't a train I could take. It was necessary because I chose not to travel down the previous evening, I didn't want to spend another night away from home. So I guess in driving here I'm really part of the problem. I joined the queue down the Don Valley, I drove a single-occupancy vehicle downtown and I contributed to the congestion, the exhaust emissions in downtown. So I guess I'm really part of the problem here. If there had been a train, I certainly would have used it. And I guess I'm not going to use this to launch a tirade against federal passenger transportation policy, even though we in Kingston lost our 7 A.M. train to Toronto. It's my personal belief that the rationalization of passenger rail services in Canada is timely and appropriate.

I have a few slides to go through. So let me just offer some thoughts particularly related to high-speed rail in the Toronto-Ottawa-Montreal corridor. I was sitting with Tom AppaRao at the dinner last night and we were thinking about all the studies which have been undertaken over the past 25 years on this corridor, going back to the late 60s with a tracked air cushion vehicle study, through the maglev studies through the high-speed rail studies. I think we agreed that if you stretched the paper out in a line you'd probably be able to extend it from Toronto to Montreal. The amount of paper that has been produced looking at this particular corridor has been tremendous.

And now there is another study under way, the task force in the provinces of Ontario and Quebec. But I'm really very encouraged, not so much at what they're studying, but who is studying it. Because the parties involved here, the Province of Ontario and the Province of Quebec, are really the parties who've got the vested interest in the technology. It's the provinces that should be interested in providing effective transportation between the centres of commerce, of government, of industry, Toronto, Ottawa, and Montreal. So I am very encouraged by the current study that's under way.

There is a lot of technology out there and Greg Wood has already spoken to the types of technology, but just let me go very quickly through these slides. First of all, the existing LRC service covers the distance from Toronto to Montreal in about 4.5 hours, which makes an average speed of 120 km/h. The electrified high-speed rail systems 240 km/h, about twice the average speed of LRC. Moving on to TGV-type of equipment, 270 km/h, south from Paris to Lyon, 290 km/h west out of Paris and some of the other systems, the Pantalino in Italy, and the ICE, which should have 300 km/h capability.

Who wants to go much faster than that. There are the new non-contact systems coming along: the Transrapid system out of Germany, which has been tested at speeds in excess of 400 km/h; and similar technology from Japan, the electro-dynamic repulsion mode maglev system. That's what the system is likely to look like eventually and they're looking at a year 2000

implementation time. That just shows the planned route in Japan from Tokyo to Osaka. The wiggly blue line following the coast is the existing Shinkansen line and the broad yellow line is the planned route for the maglev system in the early years of the 21st century. The Japanese have very recently made a commitment to put in a test line of 40 km as part of this route, just below Kofu, as it says there. And they are committing over the next seven years, the sum of three times 10^{11} yen, which translates to $2.5 billion just for a 40-km test section of this ultimate revenue line.

Now, what relevance is this to us? I guess Bob Mayes talked about demand pull, technology push. Well, they are looking at this from a demand perspective. There is a need in Japan to have this system.

The theme of this panel is transportation technology, making it happen. I guess I'll just turn that round for a moment and say why isn't it happening in Canada? It isn't happening because of two factors, I think. One is need and the second is cost.

The slide on the left-hand side represents the modal split between existing modes in the corridor. This goes back to the maglev studies that we did in the early 80s, but I think the figures are still approximately correct. Automobile captures over half of the market, air takes a quarter of it, and the rest is divided between bus and rail.

There is really no need to do anything else at the moment, there is no demand. Passengers are not really experiencing any excessive congestion, either on Highway 401 by the ground mode, or at Malton or Dorval in the air mode. So congestion is not so much of a problem that it demands us to do something yet. But, traffic is growing all the time and eventually there will be public agitation for us to do something, but we're not there yet.

Another significant factor I think is that all those modes on the left-hand side are based on oil, oil fuels. And we're 15 years past the oil crisis of the mid 1970s. Is that going to come back again? Is the OPEC cartel going to get its act in order and push the price of oil double what it is today? If indeed it is, then the cost of all of those modes is going to become a lot more expensive. And there is going to be perhaps a need for electrified ground transportation again. So nothing is happening in the corridor at the moment and there is no need to do anything because there's no problem that needs to be solved, I don't think.

The other factor, of course, is cost. Any of the technologies that I showed are very capital-intensive, a minimum of $3 billion perhaps going up to $6 billion or $7 billion, depending on which technology is selected. With capital costs of that magnitude, it's difficult to imagine the governments, either federal or provincial, being prepared to make that investment. The likely return on the investment is not sufficient such that the private sector is going to find it attractive to invest. The only way that it is going to happen, I think, is to have a partnership between those two. Government needs to provide some of the cost to increase the rate on return of investment to the private sector somewhat.

I've finished with the slides, if we could have the lights up again. Let me move then to address one of the questions that we were specifically asked to address. I left my paper over there, but it related to co-operation between users, industry, government and academia. From my perspective in university, I think that there are many people in Ontario universities who would label themselves as transportation research engineers studying in an electrical engineering school of business, even psychology and economics. For the most part, these people have traditionally worked almost in isolation. They've been content with modest-size research grants from the federal granting councils and they've done work which led to publishable material.

I think there has been a significant change in the last ten years where groups are beginning to come together and address problems which have significance for industry in the province. I think the government certainly has played a readier role as catalyst to facilitate academics working together and with the private sector and industry and government. The Province of Ontario's Technology Fund has certainly been of great assistance to us in this regard. It provided funding for the Provincial Centres of Excellence Program. And Bob Mayes has already made reference to that particular program. It allowed for

networking of researchers to come together to work with the private sector to address problems which are of strategic importance, both in the provincial program, strategic importance to the economy of the province, and the later federal program, the networks of Centres of Excellence Program to address generic type of technologies which are of strategic importance to Canada. Unfortunately, in neither of these programs was the transportation proposal successful. But I think it did show that the academics, people in universities in the province, are prepared to work together, are prepared to network with each other, with the private sector, with the government, to address significant problems. It wasn't funded. We were given the encouragement to go out and see if we could get funding elsewhere. We did that but at the federal level and the provincial level unfortunately we haven't managed to get any of those research projects funded.

I'll just leave it at that and say that I think the academic researchers in the province represent an intellectual resource which can be effectively used for the benefit of the province. I think there is a willingness among transportation research engineers to work together, to network with industry to address some of these problems. I think though we can't do that without resources. I think you're all aware that universities do not *create* economic resources, we *need* economic resources to do our thing. So we really need the resources which government or the private sector can supply to allow us to work with you to solve some of these problems and to address the transportation opportunities for the province.

SUMMARY OF THE QUESTION PERIOD FOLLOWING THE PANEL

The question period was initiated with a query about the federal government's policy regarding the funding of transportation demonstrations. An impression had been created that the federal government is moving away from demonstrations, in spite of evidence, such as presented at this symposium, that demonstrations are extremely important in establishing the viability of new technology.

It was explained that the federal government is, in fact, not abandoning demonstrations. There are several examples of ongoing federally funded transportation demonstrations: integration of urban-suburban paratransit service with line haul accessible buses in Southwestern Ontario, and articulated intercity bus operation between Montreal and Quebec, are two examples.

The federal view of the innovative process in transportation is that it starts with research, moves to development, and is successfully completed only when there is a revenue service demonstration.

It was added that the Ontario experience has been that there is a strong desire by the private sector that government funding programs should not pick winners, but should create an environment of development in which the marketplace picks the winners.

The nature of government funding of research and development was then discussed, with the concern that the lack of continuity and long-term commitment create problems for research institutions and their programs. The problems seem to be particularly acute for the Canadian Institute for Guided Ground Transport (CIGGT) that finds it difficult to maintain its programs and to attract staff.

It was explained that the sustainable funding proceedings of the federal government had been largely shifted to the three principal granting councils – the physical, social and medical research councils. As a result it seems that the share of grants that is going to transportation and related technologies has been declining over the past few years. Apparently transportation technology research and development is not perceived by the peer-review process applied by these councils, to be as important as other fields, such as bio-technology.

The reasons for this decline in importance are difficult to ascertain. There seems to be a perception that most of what we need in transportation is already available, and can be bought "off the shelf." This is actually not true, and such an attitude will eventually lead to stagnation. There could also be a cultural bias involved: our society values scientific work and technological development on one hand, while on the other, as indicated in a recent survey, a large portion of the population believes that scientists and technologists cannot be trusted.

Another reason for the funding difficulties faced by transportation research organizations could be that transportation is not a basic science; it is a discipline that draws on a number of basic scientific areas, such as advanced materials, artificial intelligence, and robotics. These are the generic technologies that often have been selected for funding.

The discussion shifted to the process of technology implementation in Japan and its use as a model for Canada. It was explained that the Japanese process consists essentially by a constant worldwide scanning and tracking of evolving technologies and inventions, carried out by individual industry members on their visits to other countries. The gathered information is shared and discussed at informal meetings of a number of industry sponsored associations. At some point, these discussions would lead to the launch of pre-competitive research in selected areas. This research would be adequately funded by the participating industries. At the end of the research period, every participant gets the results and tries to get a product to the marketplace as soon as possible.

It was pointed out that this process might not be applicable to Canada, with its relatively small population spread over a distance of 8000 km. In Canada, it would not be as easy to get people together to share information as in Japan. However, the process could

still be carried out in this country through networking with electronic bulletin boards, special conferences, and so on.

Next, the issue of a growing scarcity of engineers and scientists was raised. It is becoming evident that Canada is graduating far fewer engineers and scientists than is required for this nation's research and development programs, in spite of the fact that Canada's investment in education is higher than most other countries'.

There seems to be a number of barriers for young people who might consider an engineering and science education. Engineering requires tough subjects, such as mathematics, physics, and chemistry. These require hard work and dedication, and must be started at a fairly early age. Most young people are not willing to devote such efforts to their studies at this stage of their lives.

It also seems that women are still reluctant to choose engineering as a career, as shown by declining female enrollments in science and engineering, after some years of encouraging increases.

It was stressed that it is necessary to start to impress upon the public and our elected officials the importance of a scientific education, and that such an education must be started in the basic school system.

Young people often look at the earning potential of various professions: how much could they expect to earn as a lawyer, medical doctor, or engineer? Engineers and scientists don't fare very well in such comparisons and often suffer from other drawbacks as well, such as having to be stuck in a research laboratory, or having to work in a mine or pulp and paper mill. Also engineering is not seen as being a very glamourous or exciting profession. (How exciting would a TV show called "L.A. Engineering" be ?)

Clearly we must increase the public's awareness and appreciation of the importance of scientists and engineers, and the advantages of a science education. We must make science and engineering attractive and rewarding careers.

Next the topic of the provincial government funding of Ontario's Centres of Excellence was raised.

It was explained that the Centres of Excellence were established with a target of becoming self-funding by the fifth year of operation. That means that they would have to achieve some commercial pay-off before that time. It is these pay-offs that will create the future support, both political and industrial, for the particular research area. If there is a great deal of emphasis on Research within a Centre, less on Development, less on commercial applications, it will be increasingly difficult to get political support for investment in further investigations. Hence, in the Centres the commercial applications must be addressed.

It could be argued that it was the government that terminated the Commercial Development Offices (CDOs) that were in the universities with Centres of Excellence, making commercialization more difficult. Actually the CDOs, of which there were 34, were terminated because they did not seem to be viable, and there seemed to be better ways of achieving their objectives. These ways are being explored. But it must be stressed that the "bottom line" of research must be commercial application. Of course, there will be failures, but a margin of success is needed, in order to keep going back to the government for funding.

In further discussions, it was agreed that the provincial government has done a great deal to inject research funding into universities, which has helped initiate technologically relevant research, and encouraged linkages between universities and the private sector. The result has been research leading to useful products, valuable intellectual property, and technology transfer programs. However, with the current funding cut backs, it seems that the rug has been pulled out from under such endeavours.

It must be realized that in this period of technological ferment, when materials are shifting from steel to ceramics and composites, simple microprocessors are moving to imbedded intelligence, and so on, a certain amount of research must be devoted to "scoping" or scanning the technology environment, to be aware of what is going on, and to be ready for what may be

coming next. However, even in this activity, one should have potential applications in mind.

At the conclusion of the discussions, it was pointed out that there is still a role for pure "blue-sky thinking" – a search for knowledge for knowledge's sake, for fundamental, theoretical understanding. However, such pursuits are the *true role of a university, not of a* government research institution.

CONCLUDING REMARKS

M.D. Harmelink

Mr. Harmelink is Director of the Transportation Technology and Energy Branch of the Ministry of Transportation.

Thank you, Norm, and thank you also to the panel. We are now in the final item of the agenda and I will try to keep this relatively brief. I don't want to reiterate what has been said today.

I would like to say that in organizing today's conference, we were looking for new directions, new needs, challenges, and opportunities in technology R&D and innovation that would help us to address some of the transportation needs of the 90s and beyond. And I think there is a real benefit in an exercise like this, which helps to stretch one's mind and to lift it up so that we can step back and see the forest and not see only the trees, instead of the other way around. And, in fact, sometimes we might say that there is danger of us getting up to our eyeballs in sawdust, if we don't look up and above that.

So to do this we invited some of the top experts in the field to, in fact, stretch our imaginations, to talk about some of the emerging technologies and directions and challenges and opportunities. And I think we've met our expectations.

Last night we heard from Professor Valaskakis, a very stimulating and illuminating presentation about some of the social, economic, technological changes now taking place. The fact that they're global in nature, very far reaching, and in fact very sobering. And I'd like to come back to that a little bit later.

Dr. John did an excellent job in setting the stage for discussing technologies that would enhance mobility, safety, and productivity and stated that our primary focus should be on innovation, that R&D is merely one means of achieving that, and that it's a team effort involving the end user, industry, academia, and government.

We also heard about the U.S. Transportation Policy Review and how that was developed, with some new emphasis on innovation and advanced technology, although perhaps in ways different from the ways that was done in the past.

We heard some stimulating discussions on intelligent vehicle highway systems, on urban transit, and on inter-city transportation. We have seen some of those challenges. There was a remarkable, I think, consistency of theme that ran through this.

After lunch, we shifted our emphasis to some extent to look at transportation energy and the environment and some of the challenges that may be coming at us from that direction.

And during the panel, we heard about the need for Canada to be more competitive in the marketplace. Some of the problems in making it happen. And I don't think that we've really come to the answers there, I think it's going to take a lot of hard thought and hard slogging to get to it, but the challenges are certainly there.

There have been a number of references in the press lately, a few that I would like to pick up very briefly. Reference was already made to a speech that was made by Geraldine Kenney-Wallace about research and development being equity investment. There was a recent speech to the National Forum of Science and Technology Advisory Councils by Premier Peterson of Ontario, who said, "if we are to continue to generate the wealth needed to sustain our standard of living and social programs, we must develop a vision, clear objectives, and a plan for building an internationally competitive economy, an economy based on science-based innovation." Easily said, more difficult to do.

Another comment from Harvard University Professor F.A. Westheimer speaking in Toronto, "Technological innovation is the engine that drives our economy, yet we in North America shy away from stressing science and mathematics in our elementary schools, or teaching science and mathematics to our college students. Other nations can manage it, and it shows in the quality of their industrial products. Why can't we?" Reference was already made this afternoon that this is a very long-term, far reaching problem, one that won't be solved overnight, but which is a major challenge to Canada.

Another speech on investing in the future by government house leader Harvey Andre, speaking in Toronto, "One of the most vital tools we must use to prepare ourselves for world competition is technology, yet we face constraints. We are weak in innovation and outward orientation. Research has not been tied to industry needs, we are slow to commercialize. There is also a serious lack of private sector investment in technology and product development. The fact is that more than 70% of Canadian companies have no in-house engineering capability. Only three manufacturing companies in a hundred do any research, and less than half of them use any of the 18 key industrial technologies."

Bob Mayes made reference to the recent survey in Canada about how much Canadians know about basic science. The results were fairly pathetic. That may or may not be unexpected I'm not sure. However, perhaps one of the more disturbing aspects of that, as was already mentioned, is that 40% of the population distrust science and engineering. They feel that there's too much control by scientists and engineers over the environment. On the other hand, 45% believe that there's a lot to astrology. Quite scientific.

But, also disturbing was an article headlined, "Educators Are Skeptical of the Science Survey." As they said, what does it really matter whether you know that an electron is smaller than an atom? Or who cares how long it takes for the earth to revolve around the sun? It is a reflection, I think, of many of the values or interests in our society. How do we move in the direction of greater scientific literacy?

Another reference says that 75% of our elementary school teachers have never taken a university-level science course. Why not? Perhaps they weren't interested, perhaps it was easier to take other courses. The fact is, these are the people who are in the best position to instill some enthusiasm for science and engineering in our young people.

Another reference, an article by David Crane, who couldn't be here today, saying that R&D is the key to future economic vitality. He was quoting from John Ross, executive Vice-President of Northern Telecom, who said, "I think it is important to recognize that the rate of research and development investment is an indicator of the future industrial vitality of the country. The level of R&D spending is an indicator of the rate of investment in new products and processes. It is a measure not of how competitive Canada is today, but how competitive Canada will be tomorrow." And at the end of the article, he points out that the South Koreans have just announced an ambitious five-year, $38-billion U.S. plan to become one of the world's top ten high-technology nations by the year 2000. The strategy includes government help for industry through grants, low-cost loans and tax incentives. It raises the question: if the South Koreans can devise a strategy for their future, why can't Canadians?

I believe one of the values of the address given by Professor Valaskakis last night was that, in fact, he didn't pull punches. That he presented the situation for Canada/North America in rather blunt terms. And I'd like to bring in here a couple of comments that have been made. One comes from a relatively recent Japanese book. I think the author's name was Akio Morita. He was the one who suggested that in the trade disputes with

the United States, Japan really ought to show who has the upper hand by withholding computer chips from the Americans and selling them to the Russians. That was perhaps a book published a year or so ago. It might not have the same threat to it as it had previously.

One of the other things he said, though, and this was a point that was also made by Bill Spreitzer, is that what America has to learn, and by implication what Japan has already learned, is how to turn technology into business. And Bill Spreitzer's comments were, we may be technically ahead, we may even make some of the major R&D discoveries, but organizationally we are behind. And we have to find some way, and I'm not saying we have answers, we have to develop and work on how we're going to achieve these answers.

Another quote taken from a Japanese technology magazine: "Canada is a third-world country that happens to have a high standard of living." I believe that was a rather uneasy chuckle I just heard. And it could say many things. It could say that we perhaps are not as far ahead as we would like to be. It could say that we have a high standard of living and we are living beyond our means. But it could also point to a real danger signal. And that is that as long as we feel we have a relatively high standard of living, we may not see the need to do very much about it.

I'd like to run from that into a little quote by Will Rogers: "Even if you're on the right track, you'll get run over if you just sit there."

Well, these are a few of the messages that have come out today. I believe certainly for us the conference has been very worthwhile. It's not the kind of conference we would hold every year. But I hope you would agree that every once in a while, we have to stand back and assess the direction we're taking.

Clearly, our interaction with our partners does not cease with this conference. Far from it. We have on-going contact with almost everyone in the room and this, of course, will continue. And, hopefully, from today's conference our liaison can be richer and better focused on the needs of tomorrow.

We will be preparing a compendium of papers presented here. One last call: if you haven't left your business card to get a copy of that, we would ask you to do that as you leave.

In closing, I would like to thank all of the speakers and panelists without whom this conference would not have been possible. I'd like to thank you for your stimulating and informative suggestions. And also in closing, I would like to thank those people who have put so much into organizing this conference and ensuring that it ran smoothly. I'd like to thank my head of administration, Irene Rapa, her assistants, Jennifer Williams and Melinda Hamilton, for organizing the conference facilities and the displays. I'd also like to thank Wayne Wagner, our research lab supervisor, for his help in setting up the displays. I'd also like to thank Junette Douglin and Mike Ernesaks for spearheading the organization of the conference and its agenda and lining up the speakers.

This comment should not be misinterpreted, but I almost feel like the Queen Mother, who at one point was so confident that things would work well that she could sit down, knowing that someone would have a chair there behind her. That's how I felt today and I really do want to thank all of those at the ministry and outside the ministry who have made it possible. Thank you very much.

APPENDIX

TECHNOLOGY, VEHICLES, HIGHWAYS AND FUTURE TRANSPORTATION

William M. Spreitzer

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For presentation to
Association of Electronic Technology for
Automotive Traffic and Driving; MITI
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ABSTRACT

Advanced technology offers much potential for improved ground transportation. Improvements in electronics, communications, computers, controls, sensors and actuators are being applied to ground transportation vehicles. In turn, use of such vehicles will result in improved highway and traffic safety, better travel efficiency, optimal use of facilities, lower energy consumption and enhanced environmental quality.

The transportation system is large and complex. To attain maximum benefits, public sector/private sector co-operation is needed. Government and industry must work together to conceive, design, develop and apply the road/vehicle systems for the decades ahead.

General Motors has been a visionary and a leader in the efforts to develop the technology and to organize the national programs needed to make significant progress. This paper describes the efforts of General Motors in this important subject. It covers activities across the entire Corporation – from Technical Staffs to Operating Divisions. It describes past programs, present activities and future needs. It emphasizes technical activities but covers economic, social and institutional factors as well.

Technical program discussions range from work in highway communications (HYCOM), Driver Aid Information and Routing (DAIR) and Electronic Route Guidance Systems (ERGS) in the 1950s and '60s through more recent work in Motorist Information Services (MIS), Near Obstacle Detection Systems (NODS), Highway Driver's Assistant (HDA) and vision enhancement. Included are several programs over the years in automated highways.

Society stands at the threshold of significant improvements in ground transportation through the application of technology. General Motors is committed to helping make

future transportation safe, efficient, economic, practical and pleasurable. Advanced technology offers one path to that goal.

Advanced technology has the promise of continued and substantial improvements in transportation. History demonstrates significant progress in the efficiency, availability, economics and environmental compatibility of transportation services. Progress over time has been spectacular, looking at what has been accomplished in this century alone. Now there is a growing recognition of the need for substantial further progress. There are expectations that advancements in electronics, communications, computers, controls, sensors and actuators can be applied to ground transportation vehicles and the transportation networks upon which they operate. In turn, use of such new systems will result in improved highway and traffic safety, better travel efficiency, optimal use of facilities, lower overall energy consumption and enhanced environmental quality.

There appears to be preliminary agreement among government, industry and the users of transportation facilities and services that improvements and advancements from technology are possible and attainable. However, there is considerable additional work needed to define the detail of what is to be done, how it should be done, when it should be done and by whom. The needed next steps are for the responsible parties to get together and answer such questions.

Fortunately, such work has been underway for several years. Examples of joint plans and programs exist in Europe (PROMETHEUS), Japan (IVS) and the United States (the U.S. Department of Transportation National Transportation Policy Study, Mobility 2000). The transportation system of developed countries is typically large and complex. In most cases the transportation facilities are owned by government in the name of the people. Those facilities are used by a large number of individuals and organizations – both private and public. The equipment used in that process – both the vehicles and the supporting infrastructure – is supplied by a significantly large number of suppliers, both domestic and foreign. Thus, in order to plan for and attain maximum benefits in future transportation, public sector/private sector co-operation is needed. This co-operation is needed to a degree that has not been pursued in the past. It will involve participants that will be somewhat new to the process (e.g., the computer, electronics and communications industries). It will likely involve partnerships and arrangements for which there is little or no precedent. The effort will require that government and industry work together to conceive, design, develop and apply the transportation systems – notably the road/vehicle transportation systems – for the decades ahead.

It would appear that together we face a substantial challenge. That challenge is for all of us to co-operatively consider the detail of the future transportation system. That challenge includes consideration of the issues raised earlier. What is it, specifically, that needs to be done? How should it be done? By whom? What will be the benefits? Are they commensurate with the costs? How do we get from here to there?

The answers to those questions are a responsibility for all of us – representatives of government, industry, universities and society. The quest for the answers is not simple

and easily done. The issues are vast in nature and complex in form. Progress is being made.

But where do we go from here? Let me offer a few suggestions.

1/ To answer the questions of competing domestic programs or international co-operative programs, there needs to be increased dialogue between the active parties.

2/ This dialogue needs to be conducted with the participation of both public sector and private sector interests.

3/ Such discussions need to include both policy and also technical elements.

4/ The interactions, deliberations and actions should happen now rather than later so that potential benefits and efficiencies can be identified and pursued before potential design or policy impediments are in place.

5/ One possible place to begin might be in the establishment of system standards or recommended practices.

So how do we, collectively, get this process started? Who should take the initiative – government, industry, professional and technical societies, the intellectual community through the universities or other interested parties? In Europe it appears to have happened several ways – both with industry initiative and with government initiative – and with the participation of all interested parties. In Japan, it appears to be a joint public sector/private sector co-operation right from the start. In the United States we appear to have strong motivation and interest in government at both the Federal and State and local levels, in industry and in the universities. But we haven't yet decided on how we're going to get together although there are some discussions underway. As an optimistic idealist, it seems to me that we'll get it all worked out. It's just a matter of time. But if you agree that some level of international co-operation is potentially advantageous and should be expedited, let me raise a question. What can each of us do, right away, to help expedite the process of reaching decisions in this important matter?

General Motors has been a visionary and a leader in the efforts to develop the technology and to encourage the organization of national co-operative programs in order to make progress in transportation systems. This paper describes past and current efforts of General Motors in this important subject. In doing so, it covers activities across the entire Corporation – from Technical Staffs to Operating Divisions. It covers a substantial time period – from the 1950s through the present. The paper emphasizes technical activities but mentions economic, social and institutional factors as well.

It is concluded that society stands at the threshold of significant improvements to an already impressive ground transportation system through the application of

technology. General Motors, as a leading contributor to and beneficiary of the world's transportation systems, is committed to helping make future transportation even better than it is today – safe, efficient, economic, practical, and pleasurable.

Discussion

The interdependence of cities and their infrastructure, including transportation, is well documented (Ausubel and Herman, 1988). The efficient and safe movements of people and things are essential to the efficiency, livability and enjoyment of metropolitan areas and agglomerations of people and social and economic activities.

Today, there is growing concern about the state of the infrastructure in cities of the world. There is concern about the ability of the current transportation system to adequately serve present day needs. There is particular concern about coping with future transportation needs (Agnew, 1988; Pisarski, 1987). Increasingly, there is concern about resolving such concerns with conventional approaches. It is concluded that massive new road construction will not be practical in many cities for reasons of available space, economic costs and added pressures on the environment such as air quality, visual intrusion and noise level. There is skepticism about the ability of improved and expanded public transportation to accommodate future transportation demands in all but a few very high population density and large geographic area communities. There is a lack of experience or evidence to suggest that people will agree to reductions in their mobility through limitations on travel or improved communications as a substitute for travel. It appears that there will be continued increases in the levels of transportation need for people and for goods (U.S. Department of Transportation, 1988) .

Such considerations have prompted increasing attention to the satisfaction of future transportation needs and to a resolution of the relative merits of different approaches to their accommodation (Mobility 2000, 1989). One major consideration in such analyses is the potential role of advanced technology in the improvement of transportation systems and services and the satisfaction of increased transportation demands by making much better use of existing facilities – "smart cars and smart highways" – through better application of existing technology and the utilization of future technological advancements.

Such transportation considerations based on technological advancements have come to be known as "Intelligent Vehicle/Highway Systems" or IVHS. The subject area covers many prospects from off the shelf technology applied in new ways to solve existing problems to very advanced technologies applied to future needs in ways that are yet to be defined in detail.

Therefore, it seems appropriate to start with a definition (Figure 1). Intelligent Vehicle/Highway Systems, or IVHS, are defined for purposes of this discussion as "technological developments which improve either highway safety, system operating efficiency, environmental quality or energy utilization in transportation through improved interactions between roads, vehicles and their drivers". Such developments (Figure 2) include a continuum of examples which range from presently available

advanced traffic management systems to an eventual possibility of automated highways. Included within that definition are motorist information and communications systems, head up displays, near obstacle detection, headway control, night and bad weather vision enhancement, lane detection, lane following, forward looking obstacle detection, collision warning, collision avoidance, sensors and actuators for each of these purposes and (eventually) automatic chauffeuring and automated highways.

General Motors has been a visionary and a leader in the efforts to develop the technology and to help organize the national programs needed to make significant progress. These efforts have been both Corporate-wide in nature and also represent the individual initiatives of a broad range of the Corporate activities. They have been conducted within the Technical Staffs Group, in the Car and Truck Groups, in the Accessory and Components Group and (more recently) in the GM Hughes Electronics Group and the Electronic Data Systems (EDS) Corporation.

Several examples of work over the past four decades are as follows:

1/ Theory of Traffic Flow, Traffic Dynamics

Beginning in the mid-50s, research scientists at the GM Research Laboratories began work on the development of a mathematical foundation for the description and understanding of vehicular traffic on roadways (Chandler, Herman and Montroll, 1958 and Herman and Gardels, 1963). The objectives were to develop mathematically rigorous theories of the interactions between vehicles, drivers and roadways and to validate these theories and their models through observations and experiments. In turn, the models could then be applied to the evaluation of various traffic engineering improvements. This work was highly successful and has been applied to solutions of a wide variety of traffic problems. Included are applications in single lane traffic flow, multiple lane traffic flow, traffic networks and transit as well as personal (automobile) transportation.

2/ Automated Highways

Also in the 1950s, work began in the GM Research Laboratories on the concept of the automated highway (Bidwell and Cataldo, 1958; Gardels, 1960; Morrison, Welch and Hanysz, 1961; Canty and Sobey, 1969; Bender et al., 1981). That work included full scale demonstrations of wire-guided systems and detailed implementation studies of metropolitan area-wide installations.

3/ Highway Communications Systems

At about this same time, work began on a variety of highway communications systems. One of the first in a series of programs was the Highway-to-Car Communications System or HY-COM (GMR Highway Information System, 1959; HY-COM, Highway Communicator, 1961). Originated by the GM Research Laboratories and developed in co-operation with the (then) Delco Radio Division of the Corporation, the system utilized simple, low cost, low frequency roadside transmitters to broadcast information

or warning messages to passing drivers. Another example of work in this area was the Driver Aid, Information and Routing (DAIR) System (Hanysz, Quinn, Stevens and Trabold, 1966). DAIR included a coded communications link for requesting emergency service or aid, two-way voice communications, an in-car traffic sign repeater (in-vehicle signing), an audio broadcast for roadside messages as in HY-COM and a routing system to guide drivers along a pre-selected route to a destination. DAIR was a precursor to a contract with the (then) U.S. Bureau of Public Roads for the design, development and demonstration of an Experimental Route Guidance System (ERGS) which was done for the U.S. Department of Transportation by the GM Research Laboratories and the Delco Radio Division (GM Research Laboratories and Delco Radio Division, 1968). ERGS made use of electronic equipment in both the vehicle and the roadway to supplying routing instructions to an intended destination. This effort included extensive human factors efforts in the design of the driver display.

Another example of highway communications work done in co-operation with public agencies was the Detroit Citizens Band Radio Driver Aid Network (Quinn, Spreitzer and Gibson, 1967; Bauer, Malo and Quinn, 1968; Quinn, 1969). Done with the City of Detroit Department of Streets and Traffic along the John C. Lodge Expressway, the system collected information on traffic problems from Citizens Band Radio-equipped vehicles and drivers and relayed that information to vehicles in the traffic stream over standard broadcast radio. Eventually, this and previous work led to General Motors financial support of the national Regional Emergency Action Coordinating Team (REACT) which used volunteer teams and Citizens Band Radio to monitor emergencies and traffic and provide information to public authorities and radio stations.

4/ Traffic Engineering

General Motors interest in roads, highways, traffic and drivers goes back many years. As just a few examples, we were a sponsor of the Lincoln Highway Association, sponsored a Good Roads Essay Contest and have been a long standing participant in professional and technical associations involved in highways and highway safety. One major effort related to adaptation of the von Stein Traffic Funnel ("green-for-go") concept on a stretch of highway adjacent to the General Motors Technical Center in Warren, Michigan in co-operation with the Macomb County Road Commission (Morrison, Underwood and Bierley, 1962). Traffic Pacer utilized pre-signals and advisory speed signs to form platoons of moving vehicles so that they would arrive at intersections at the onset of the green traffic signal phase. Gaps created between the platoons provided for cross traffic. The full scale demonstration provided proof of a significant increase in intersection capacity. In general, drivers surveyed indicated a preference for the Traffic Pacer System over a "progressive" system or conventional systems.

5/ Transportation Systems

All of these efforts led to GM's involvement in full transportation systems activities – both personal, ground vehicle systems and public transportation systems. As men-

tioned earlier, work had been conducted in automated highways and automated vehicle control. These technical developments could be applied to public transportation as well as personal transportation. In 1967-68, the GM Research Laboratories completed an implementation study of new and improved systems of urban transportation for the U.S. Department of Housing and Urban Development (Canty and Sobey, 1969; U.S. Department of Housing and Urban Development, 1969). This study included detailed analysis of the design and deployment of seven candidate systems in real cities. Included were a bus transit system operating on exclusive rights-of-way (Metro-Mode), a rail pallet-vehicle carrying commuter system, an automated highway, a bi-modal bus operating on an automated guideway for the long distance portion of its trips, a people mover concept dubbed Network Cab which operated on a closed automated network in a downtown area, a Multimodal Capsule in which a small passenger compartment was successively transported by two or more carrier vehicles to eliminate the need for people transfers and a Demand Responsive or Dial-a-Bus system. All of these concepts included advanced technology in the vehicle, in the guideways and in the command, control and communications links.

In turn, such work led to a variety of systems studies. A few examples include work in characterizing traffic in metropolitan areas (Chang and Herman, 1978); studies of the relative merits of different ways of improving fuel consumption (Chang, Evans, Herman and Wasielewski, 1977); analyzing the effects of improved traffic flow (Chang and Horowitz, 1979) and reviewing the impact of congestion on fuel consumption and environmental quality (Tobin, 1979).

Current Intelligent Vehicle/Highway Systems (IVHS) work in General Motors includes efforts in advanced traffic management systems, advanced driver information systems, advanced vehicle control and research and development in a broad range of supporting technology and components such as sensors and actuators. The work is being conducted throughout the organization – from the Technical Staffs Group to the many Operating Divisions. As shown in Figure 3, the work ranges across the GM Advanced Engineering Staff and the GM Research Laboratories in the Technical Staffs Group through the GM Hughes Electronics (GMHE) and Electronic Data Systems (EDS) Corporations. Much of the current work is proprietary but we can discuss several of the programs.

Increasingly, real time traffic information has become available as a result of work by cities and metropolitan areas in advanced traffic management systems (OECD, 1988). Typically, such information is used in traffic signal control and in traffic management on freeway ramps or in accommodating arriving traffic or in helping to disperse departing traffic from special events or around road construction or repair. At the same time, increasing intelligence is being provided in vehicles through automatic vehicle identification, automatic vehicle location and in-vehicle navigation and trip-planning capability. It is an obvious next step to tie the traffic data and traffic management center capability to the in-vehicle capability through appropriate communications, both voice and data. It is also clear that these advances apply to truck and commercial and transit operations as well as personal automobile usage. In fact, there are a number of

cost/beneficial examples in commercial and fleet management operations already in use.

General Motors has a number of active programs in the overall subject area of Motorist Information Services (MIS) (Agnew, 1988). Notable among these is the Mobile Information Services activity of the GM Advanced Engineering Staff (AES) (Frank, 1989). Working with several Divisions of General Motors, GM AES has designed and built a demonstration vehicle equipped with a liquid crystal, reconfigurable display with an infrared touch screen for the driver interface; seven dedicated switches for feature selection on climate control, travel assistance, office/business features and communications; a cellular telephone; a facsimile machine; a thermal printer; compact disk for data and software storage and a far speak (microphone above the windshield), speaker dependent, voice recognition capability. This system provides for a variety of travel, communications and business services.

As an example of the travel assistance available, the MIS includes navigation, destination assistance, traffic advisories and route selection. As shown in Figure 4, the dead reckoning, map matching navigation system is complemented by "yellow pages" and current traffic condition information to provide the driver with advice on an optimized route to a given destination.

A complement to the MIS work is the Delco Electronics Corporation work on NAVICAR, an in-vehicle navigation system intended for introduction as a production option at some point in the future. The NAVICAR system consists of a controller, interfaced to a raster scan, color cathode ray tube; a compact disk player; wheel sensor information; a compass and navigation algorithms derived from technology purchased from ETAK Corporation. NAVICAR is integrated with the vehicle anti-lock brake system wheel sensors and shares the cathode ray tube with other vehicle information and control display systems. Figure 5 is a schematic of the NAVICAR System and Figure 6 shows a typical map display.

Other work in the vehicle information and communications area is exemplified by work at the Hughes Aircraft Company in automatic vehicle location. The Hughes Vehicle Location System (VLS) was conceived to provide fleet managers and service assistance organizations with the locations of specific vehicles (United States Patent 4 740 792, 1988). As shown in Figure 7, VLS is a satellite-dependent system in which the architecture has been optimized for serving millions of vehicles by minimizing the demand on the vehicle's electronics. As illustrated, three satellites are used to relay vehicle transmissions. Therefore, no costly receiver or synchronization is required in the vehicle. A central computational facility uses the signals to compute the location of the vehicle transmission and periodically notifies fleet managers, police, automobile clubs and others over computer-to-computer links using the existing telephone network.

Autonomous vehicle capability and traffic management center services can be greatly enhanced by co-operation and communication between the two. Early efforts are being expended to demonstrate the advantages of such systems in a real world

setting. One such example is the Pathfinder Program being done in co-operation with the California Department of Transportation (Caltrans), the U.S. Department of Transportation (DOT) and General Motors (Betsold, 1989). Pathfinder will tie twenty-five specially-equipped Oldsmobile Delta 88 automobiles together with advanced traffic management center capabilities along the Santa Monica Freeway Corridor in the Los Angeles Metropolitan Region as shown in Figure 8. The so-called "Smart Corridor" runs roughly twelve miles from the Pacific Ocean at Santa Monica, California to downtown Los Angeles. Heavily instrumented with a variety of traffic detectors, the Freeway and the parallel arterials can be monitored with regard to traffic flow and status. In turn, that information can be provided back to the drivers of the specially-equipped Pathfinder vehicles with advice on alternate paths to their intended destinations. Conduct of the demonstration will include measurement of the benefits to the drivers of the Pathfinder vehicles in terms of improved travel time, lower fuel consumption (and improved air quality), improved traffic safety and better travel experience. Conceived during a special Caltrans planning conference in October of 1986, Pathfinder will begin demonstration operations early in 1990.

Currently, General Motors is seeking additional opportunities in demonstrations of motorist information services concepts in other geographic areas in co-operation with public agencies and other private sector interests. The objectives are to demonstrate the benefits and capabilities of such systems and to develop the necessary justification for wider scale deployment of such systems in the near future.

Fundamental research in vehicle information and navigation systems, including human factors studies, continues at the GM Research Laboratories (Takasaki and Wasielewski, 1989). This on-going work addresses questions with regard to what type of information vehicle operators want, what they need, how such information might be provided in a cost-effective manner and how it can be provided without detracting from the important task of operating the vehicle in a completely safe and effective manner by a wide range of users of a varied demographic sampling.

Advanced Driver Aids

Another set of on-going programs relates to advanced driver aids. Typically these are instances where capabilities are introduced in the vehicle or in the highway separately and independently with immediate benefits that justify their costs. It is expected that as the utility of the devices are demonstrated and the reliability and cost of the technology improves, many of the vehicle and highway independent capabilities will be integrated into a "smart car/smart highway" system or true IVHS. There are several examples in the current General Motors Programs in IVHS.

Delco Electronics Corporation, working with Hughes Aircraft and other General Motors activities, has programs in head up displays (HUD) and near obstacle detection systems (NODS). The Head Up Display (HUD) shown in Figure 9 is presently available as a production option in the Oldsmobile Cutlass Supreme and the Pontiac Grand Prix. Specifications for the HUD system are listed in Figure 10. HUD provides assistance to the driver in two important ways. First, the driver can keep looking at the road ahead while collecting HUD information and acting upon it. Second, by focusing

the HUD image two or more meters forward of the driver, it eliminates the need for the eyes to reaccommodate from the road to the image.

The Near Obstacle Detection System (NODS) is based on microwave radar and continuous wave doppler technology. It is located in the rear bumper of a vehicle as shown in Figure 11 and detects the presence of moving objects within an area behind the vehicle. With the car in reverse gear and when an object is detected, the driver is alerted to the potential obstruction through a panel indicator and an audio signal. Future NODS systems will incorporate side detection to aid the driver during lane changes as shown in Figure 12. The system is activated when the transmission is in a forward gear and the turn signal is engaged. Objects in a driver's "blind spot" are detected and the driver is signalled. Taking the concept a step further, collision avoidance systems, using the same principles, can be pursued.

An example of other applications of such systems is shown in the Visibility Enhancement Van (VEV), shown in Figure 13, built co-operatively between Delco Electronics and the Advanced Vehicle Engineering Group of GM's Truck and Bus Division. The vehicle was designed to complement the driver's awareness of the surrounding environment. Two systems were provided -- a video rear vision system and a near obstacle detection system. Intended as a mirror replacement technology, the video rear vision, shown in a close-up photograph in Figure 14, eliminates blind zones both along the sides and rear of the vehicle. The system uses five microcameras and three five inch full color liquid crystal displays as shown in Figure 15. A Multimode Near Obstacle Detection System (MNODS) was designed by Delco Systems Operations. It is capable of detecting objects at the front, rear or in the blind zone of the vehicle. It is a radar-based system with a range of approximately five meters. It has both a graphic and audible warning when an object is detected. Graphic information includes distance as well as approximate location (left side, center, right side) and is displayed on one of the liquid crystal displays of the rear video system.

Advanced Vehicle Controls

Still more advanced and longer range work is covered under this heading of advanced vehicle controls. Two examples of work underway are the so-called Autonomous Mobility Project of the GM Research Laboratories (GMR) Computer Science Department and the Highway Driver's Assistant (HDA) Project of the GMR Trilby Vehicle Systems Department.

The Autonomous Mobility Project builds from earlier GMR efforts in computer vision and intelligent robotics for manufacturing applications. Obvious opportunities exist in adaptive material delivery systems and vehicle navigation. Project research areas include navigation and obstacle avoidance, range image analysis, color vision, VLSI image processing and reasoning about uncertainty. An AutoNav research testbed has been developed. It is a wholly autonomous vehicle capable of moving freely at economical speeds. Shown in Figure 16, it is capable of performing tasks requiring mobility, working from goal-oriented commands in the form "Deliver a pallet of Part X to Machine Y". Navigation and obstacle avoidance is accomplished via a map of

load/unload stations, continuous position estimation by odometry, position recalibration by locating targets using on-board vision and ultrasonic sensors. AutoNav navigates by sighting targets using a special GMR VLSI image processor shown in Figure 17. The desired path is specified and motion simulated using a CAD-like graphics system. That path is downloaded to the vehicle over a RF data link and the ultrasonic sensors detect possible collisions and slow or halt the vehicle. Obvious benefits include elimination of the need for a guidepath (for example, a buried wire). Guidepath functions are replaced by separate mechanisms for path definition and navigation. System setup is simplified and path layouts can be changed rapidly and easily via software programs.

The Highway Driver's Assistant (HDA) Project is directed toward integration of driver information and vehicle control functions. It includes work in navigation, real-time traffic information, route planning, route guidance, hazard warning (collision, skid), headway control and lane control. The activity supports a range of IVHS objectives. Test vehicles include a full-feature navigation system with color map display and synthesized voice for real-time traffic information and route guidance. The information is presented to the driver in an optimum way to minimize distraction from the driving task. Travel information includes map features, road signs and "yellow pages". Safety and convenience features include out-of-lane warning, collision warning, skid warning, headway control, lane control and a driving performance monitor. There has been careful cross-function integration with human factors design and evaluation.

An HDA Test Van is shown in Figure 18. As a "laboratory on wheels", the van is equipped to collect data from the road for several HDA functions, for example lane sensing. The interior of the van is shown in Figure 19 and is rearranged to accommodate a computer system with image processing equipment, video equipment, audio components, a patch panel, instrumentation, power meters, an inverter and auxiliary batteries. Room has been provided for an experimenter and a computer terminal. The sensors installed in the van include a monochrome CCD video camera to acquire the road images, a steering-wheel angle sensor and a pulse-based vehicle speed sensor.

Closing

The activities and programs described in this paper are but a portion of the attention that General Motors has given to the topics of advanced technology for the vehicle and for the highway and to the subject of Intelligent Vehicle/Highway Systems. These descriptions do not represent an exhaustive list of all that has been done or is being done presently. However, they do represent a sampling of the current internal and co-operative programs. In addition to what has been described here, General Motors personnel participated in the conception of Pathfinder and continue to be involved in the Pathfinder Demonstration Program through service on the Program Advisory Committee. GM continues to work with the U.S. Department of Transportation Federal Highway Administration and the National Highway and Traffic Safety Administration and other State and Local government agencies in identifying and pursuing experiments and demonstrations in advanced vehicle/highway technology .

GM has been active in efforts to develop a National co-operative Program in Intelligent Vehicle/Highway Systems. GM provides financial support or advisory participation or both in the activities in IVHS at the University of California, Berkeley Program for Advanced Technology for the Highway (PATH), at the University of Michigan Transportation Research Institute IVHS Program, at several other university based programs which are presently under development and with several State Departments of Transportation.

GM, through Adam Opel AG, is involved in the PROMETHEUS Program in Europe and, through General Motors Overseas Corporation (GMOC) and Isuzu, with the Advanced Mobile Traffic Information and Communications System (AMTICS) in Japan.

Staff members of the Corporation are active in the continuing IVHS efforts of Mobility 2000 Group (an informal, self-appointed group of representatives from government, universities, industry and other public and private sector organizations); the National Research Council Transportation Research Board (which in addition to on-going IVHS committee activities is about to embark on a jointly-funded, industry and government-sponsored study on advanced technology for the highway and for the vehicle); the American Association of State Highway and Transportation Officials (MSHTO), the Highway Users Federation for Safety and Mobility (HUFsam); the Institute of Electrical and Electronics Engineers Vehicle Navigation and Information Systems (VNIS) activity and the automotive navigational aids activity of the Motor Vehicle Council of the Society of Automotive Engineers (SAE).

General Motors has stated that the path to future advanced highways which are capable of accommodating advanced vehicles ("smart highways for smart cars and trucks") is through a joint public sector/private sector effort involving government, industry, universities and other interests in a broad national, co-operative program. To say it simply, "We believe that good roads and a pleasant driving experience help sell cars and trucks". Saying it yet another way, as a supplier of transportation equipment and a beneficiary of good transportation service, General Motors is committed to contributing to the efforts and activities through which we can provide the finest transportation possible through the application of advanced technology and an optimal investment of available transportation facilities and funding.

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DEFINITION

Intelligent Vehicle/Highway Systems are technological developments which improve

- **Highway safety**
- **Operating efficiency**
- **Environmental quality and**
- **Energy utilization**

through improved interactions between

- **Roads**
- **Vehicles and**
- **Drivers**

1. Definition of Intelligent Vehicle/Highway Systems (IVHS)

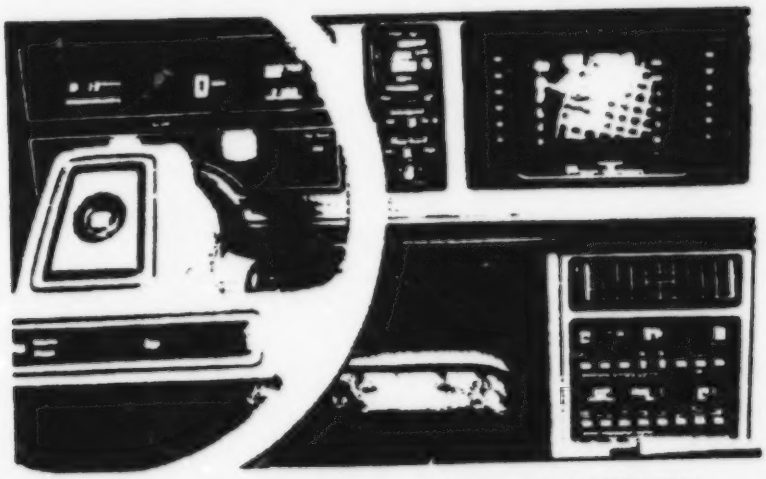
EXAMPLES

2. Examples of Intelligent Vehicle/Highway Systems (IVHS)

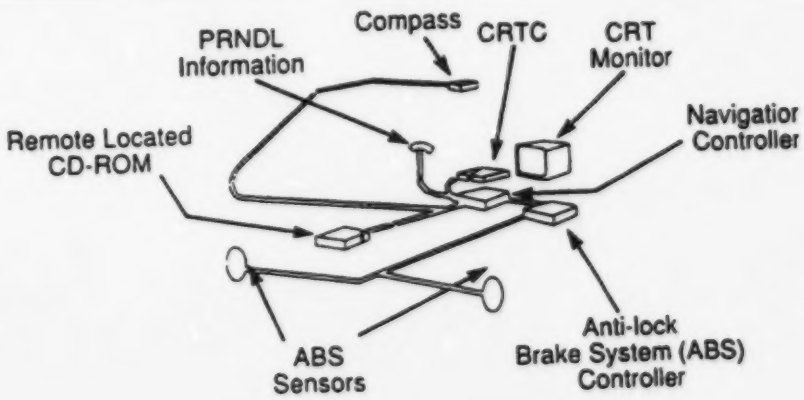
GENERAL MOTORS PROGRAMS

- **TECHNICAL STAFFS GROUP**
  - GM Advanced Engineering Staff
    - Reconfigurable Displays — Adaptive Cruise Control
    - Travel/Business Information — Vision Enhancement
  - GM Research Laboratories
    - Highway Drivers Assistant — Dashboard Displays
    - Navigational Aids — Autonomous Mobility
    - PATHFINDER
- **GMHE**
  - Delco Electronics
    - ETAK Navigator (NAVICAR)
    - Near Obstacle Detection Systems
    - Head-Up Displays
  - Hughes Aircraft
    - Cooperative Highway Study
    - Advanced Head-Up and Virtual Image Display
    - Color Projection Display
- **EDS**
  - Fleet Management Proposals

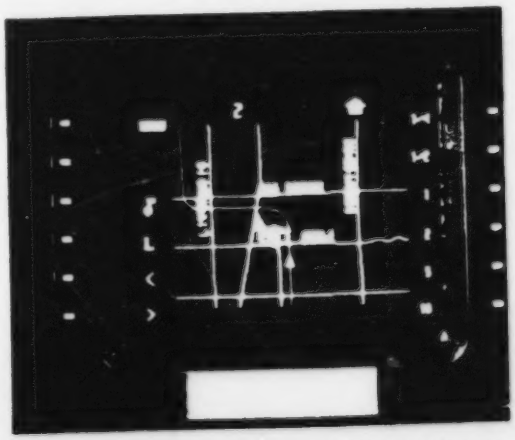
3. List of General Motors Programs in IVHS



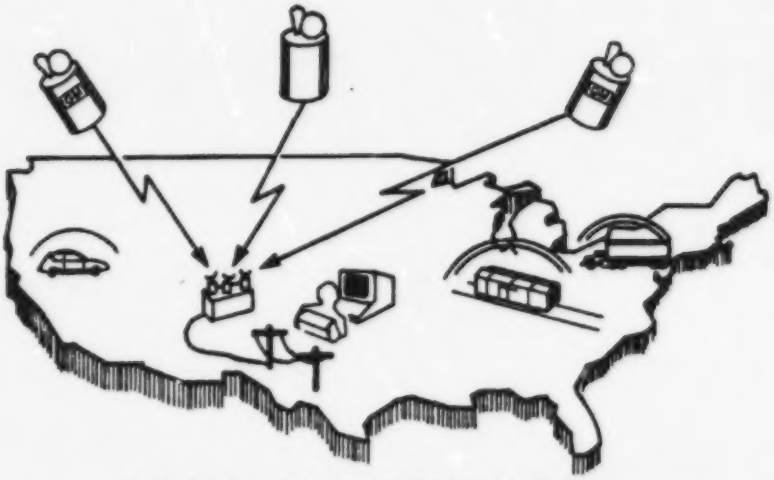
4. General Motors Motorist Information Services (MIS) Display



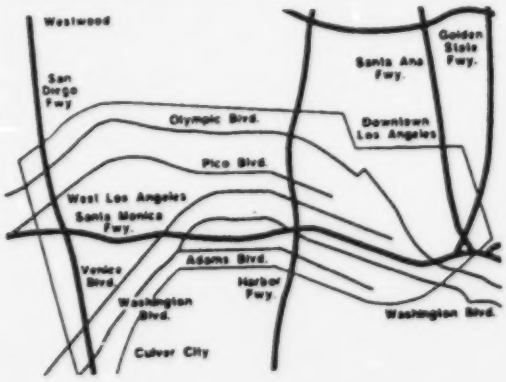
5. GMHE Delco Electronics NAVICAR System



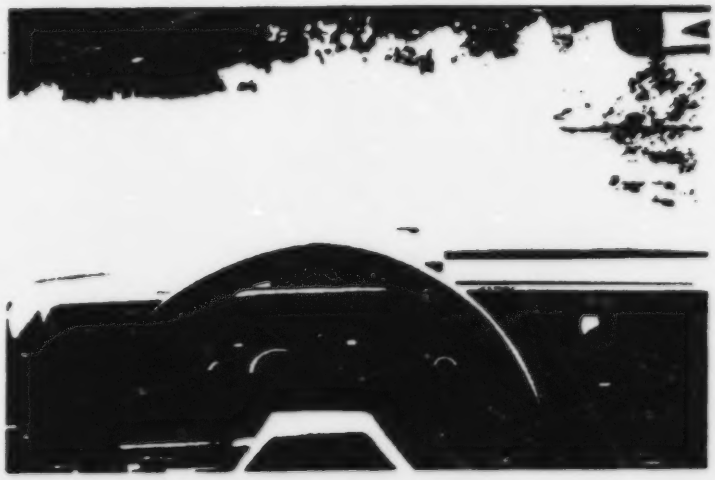
6. Map Display of the Delco Electronics NAVICAR System



7. Hughes Aircraft Company Vehicle Location System



8. Smart Corridor/Pathfinder
Demonstration Project Area

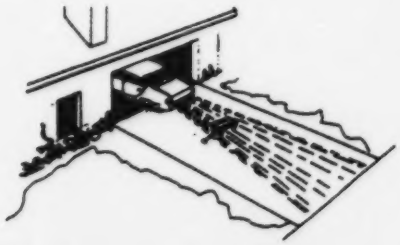


9. Delco Electronics Corporation Head Up Display (HUD)

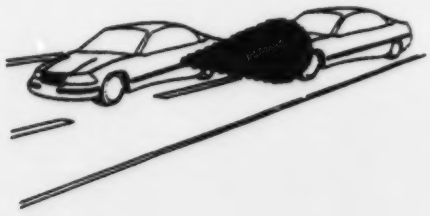
HUD SPECIFICATIONS

Image Size: 1.5 degrees x 3.0 degrees
Image Location: Azimuth - at driver's centerline
Elevation - Tiltable - -2 deg. to -6.5 deg.
Range - 2.4 meters
Brightness: Control Modes - 2 (day/night)
Maximum: 500 ft-L
Minimum: 1 ft-L
Adjustment Range - 50:1
Color: Blue-green (505 nm peak)
Eye motion box: Total - 130 mm x 130 mm
Instantaneous - 130 mm x 65 mm with manual tilt
Vertical Binocular Disparity: Avg. - < 0.7 mr
Max. - < 1.5
Weight: 8.75 kg.
Power Consumption: 3 watts, 12 vdc (nominal)

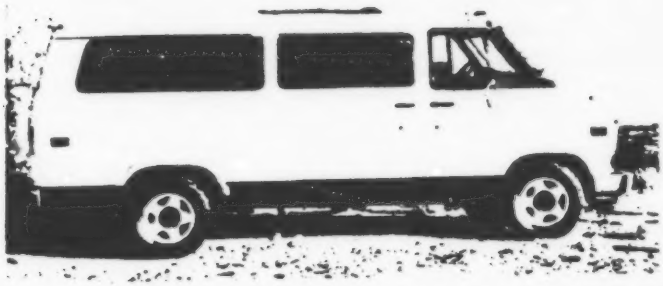
10. Delco Electronics Head Up Display Specifications



11. Delco Electronics Near Obstacle Detection System (NODS)



12. Blind Spot Obstacle Detection



13. GM Truck and Bus/Delco Electronics Vision Enhancement Van (VEV)

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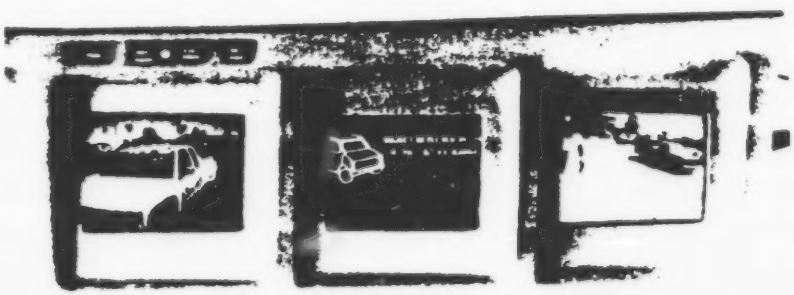
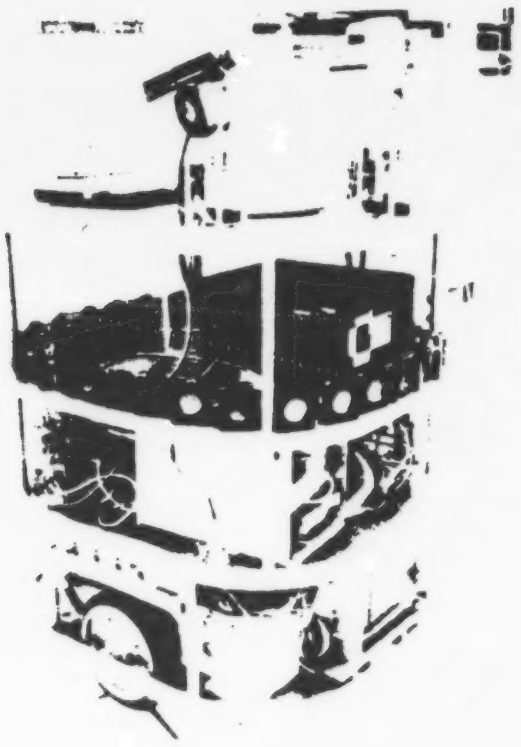
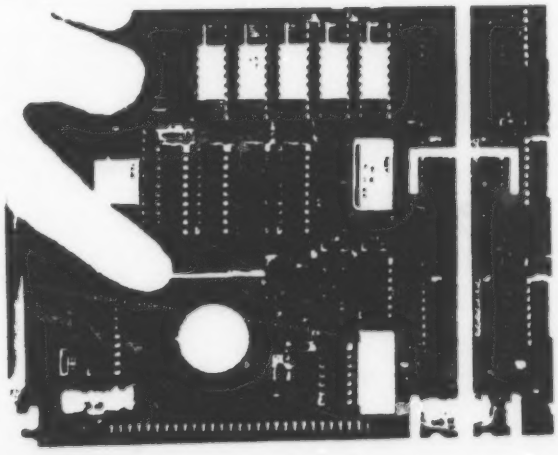
14. VEV Video Installation



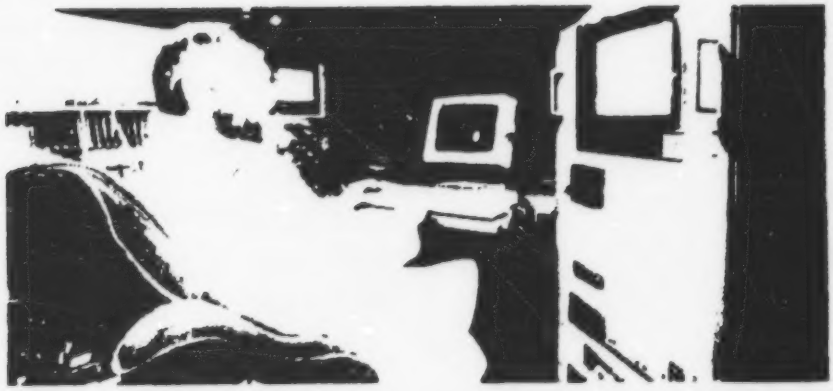
15. VEV Liquid Crystal Displays (LCD's)



16. GM Research Laboratories
AutoNav 2 Vehicle



17. GM Research Laboratories
AutoNav 2 Image Processor



18. GM Research Laboratories Highway Driver's Assistant (HDA) Sensor Van

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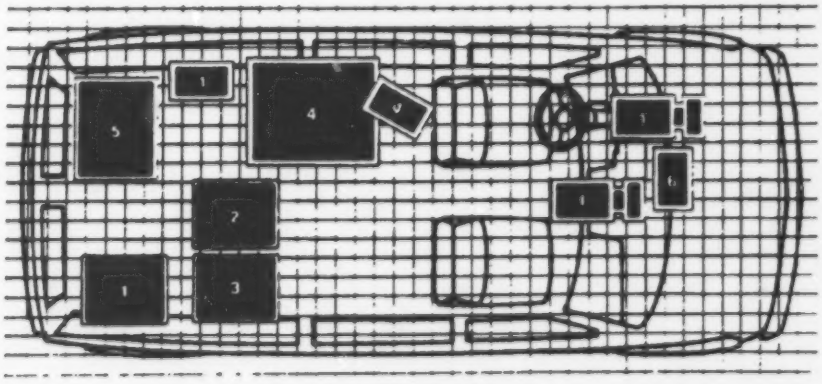
SYSTEMS

1. Sensors
   - Forward-Looking Camera
   - Magnetic Compass Wheel Rotation Sensors (ETAK)
   - Steering Wheel Angle
2. Video Equipment Rack
   - Recorder and Monitors
   - Patch Panel
3. Processing Rack
   - 68030 Microcomputers
   - Real-Time Image Processor
   - ETAK Navigator
4. Experimenter's Console
   - Computer Terminal
   - Monitor
5. Power System
   - 2 kW Inverter
6. Cellular Phone
   - Digital Modem

HDA SENSOR VAN



19. HDA Van Layout